

Guidelines for Utah's Corrective Action Process for Leaking Underground Storage Tank Sites

prepared by the
Leaking Underground Storage Tank Program
Division of Environmental Response and Remediation
Utah Department of Environmental Quality

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SECOND EDITION FINAL DRAFT

July 30, 1999

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ACKNOWLEDGMENTS

The completion of this document would not have been possible without the hard work and dedication of individuals and organizations involved with the Partners in RBCA Implementation (PIRI). Specifically, we would like to acknowledge the following members of Utah's PIRI committee:

Craig Anderson, Sinclair Oil Corporation
Steve Canning, Utah Division of Fleet Operations
John Christensen, EnviroSearch International
John Connor, Groundwater Services, Inc.
Scott Everett, Utah Division of Environmental Response and Remediation
David Friz, EWP
Geoffrey Gilman, Amoco Corporation
Kathy Harris, Delta Environmental Consultants
John Hill, Utah Petroleum Marketers Association
Gene Inglesby, Western Petroleum Marketers Association
Robin D. Jenkins, Utah Division of Environmental Response and Remediation
Rolf Lange, EnviroSearch International
Ron Love, Salt Lake City Corporation
Tom Meyer, Roy F. Weston, Inc.
Lee Peacock, Utah Petroleum Association
Jenny Phillips, RETEC
Dave Rickers, Kleinfelder
Lori Robison, SECOR International Incorporated
Victor Scherer, Utah Division of Environmental Response and Remediation
Jan Snyder, Parsons Engineering Science, Inc.
Dale Urban, Utah Division of Environmental Response and Remediation
Holly Welsh, ROCS
Steve Woodhead, Chevron Products Company
Gene Wright, Parsons Engineering Science, Inc.
Paul Zahn, Utah Division of Environmental Response and Remediation

We would also like to thank Bryan D. Whitaker, Utah Department of Environmental Quality, DERR; Kent P. Gray, Utah Department of Environmental Quality, DERR, and; Dianne Nielson, Utah Department of Environmental Quality for their support during the development of this document.

LIST OF TERMS AND DEFINITIONS

(please see Utah Admin. Code (UAC) R311-200 for definitions of other important terms not found in the following list)

- Action Levels (ALs) - Contaminant concentrations that must be met at an Alternative Monitoring Point (AMP). ALs are calculated by first determining the distance between the AMP and the receptor, then applying that distance to the exposure and cross-media transport equations (same as those for calculating RBSLs and SSCLs) to determine the contaminant concentration required at the AMP to meet the RBSL at the receptor.
- Active Remediation - Actions taken to reduce the concentrations of COC.
- Air Dispersion Factor - Attenuation of contaminants due to transport in air.
- Alternate Monitoring Points (AMPs) - Contaminant monitoring points at which contaminated media must be monitored and in which *Action Levels* (ALs) must be met. AMPs ensure that receptors will not be impacted by contaminant concentrations greater than the RBSL. AMPs are located at some site-specific distance between the source of contamination (point of compliance) and the receptor (point of exposure, POE). AMP locations are required, at a minimum, along the plume centerline, and are based on the site-specific contaminant transport regime and on a contaminant travel time of one year from the AMP to a receptor (POE).
- American Society for Testing and Materials (ASTM) - ASTM is a not-for-profit organization that writes standard test methods, specifications, practices, terminologies, guides and classifications for materials, products, systems and services that encompass metals, paints, plastics, textiles, petroleum, construction, energy, the environment, consumer products, medical services and devices, computerized systems, electronics and many other areas.
- Attenuation - The reduction in concentrations of COC in the environment with distance and time due to processes such as diffusion, dispersion, adsorption, chemical degradation and biodegradation.
- Board - The Utah Solid and Hazardous Waste Control Board.
- Cleanup Criteria - Criteria used by the Utah Department of Environmental Quality, DERR to evaluate the closure of LUST case files. These criteria are contained in Utah's Cleanup Standards Policy and include: (1) elimination of a contaminant source by removal or control; (2) evaluation of current and potential impacts to public health; (3) evaluation of current and potential impacts to the environment; (4) economic considerations and cost-effectiveness of cleanup options, and; (5) technology available for use in cleanup.
- Cleanup Levels (CLs) - see Site-Specific Cleanup Levels.
- Complete Exposure Pathway - An exposure pathway for which a transport mechanism is actively placing receptors at risk of exposure to the contamination being transported, as shown below:
 1. For the Risk Assessment Proposal **only**, an exposure pathway is considered complete when a contaminant concentration in the source zone exceeds the applicable Tier 1 criteria (Utah Tier 1 screening levels and distance to receptors), **and if one or both** of the following conditions exist at the site:
 - a. The mechanism for contaminant transport would be active in the absence of any existing or future control measures, **or**;
 - b. Receptors (POEs) could be potentially in contact with the affected media. "Potential" means anticipated changes in site conditions within 5 to 10 years.
 2. For the Risk Assessment Report, an exposure pathway is considered complete when **all** of the following conditions are present at the site:

LIST OF TERMS AND DEFINITIONS, *continued*

- a. A contaminant concentration in the source zone exceeds the applicable Tier 1 criteria (Utah Tier 1 screening levels and distance to receptors);
 - b. The mechanism for contaminant transport would be active in the absence of any existing or future control measures, *and*
 - c. Receptors (POEs) could be potentially in contact with the affected media. “Potential” means anticipated changes in site conditions within 5 to 10 years.
- Confirmation Sample - Environmental samples that are taken during or after corrective action activities and are taken to determine compliance with applicable standards.
- Constituents of Concern (COC) - Also called Contaminants of Concern. Specific constituents or chemicals that are identified for evaluation in the risk assessment process. For the purpose of this document, COCs may include BTEXN, MTBE and TPH, but do not include metals, halogenated hydrocarbons, oil and grease, or Total Recoverable Petroleum Hydrocarbons.
- Corrective Action - Activities conducted to protect human health, safety, and the environment. These may include but are not limited to, recovering free product, designing and operating cleanup equipment and actions, conducting sampling and monitoring to monitor progress of cleanup actions, implementing environmental controls, evaluating risks, and making no further action decisions.
- Corrective Action Plan (CAP) - A document prepared by an Owner/Operator that evaluates all hydrogeologic data, compares all available cleanup technologies for their technical and economic feasibility, and proposes corrective actions which may consist of source abatement or removal, monitoring, cleanup using various methods, or other methods of protecting receptors.
- Critical Distance - For Tier 1, distances between a source area and receptors (Utah Department of Environmental Quality, DERR, 1997, and Appendix G).
- Data Entry Field - A location on the Worksheets where information is input.
- Dilution Attenuation Factor (DAF) - Attenuation due to occurrence and transport of a dissolved contaminant phase.
- DERR - The Utah Division of Environmental Response and Remediation, a division of the Utah Department of Environmental Quality.
- Direct Exposure Pathway - An exposure pathway where the point of exposure is at the source area, without an impact to any other medium.
- Engineering Controls - Physical measures to keep contamination away from a receptor. Examples include fences, paving, vapor extraction and vapor barriers.
- Environmental Controls - Any effort made to reduce risks to receptors. These often involve restrictions on use or access to a site or facility to eliminate or minimize potential exposure to COC. These may also include engineering controls (measures to keep contamination away from a receptor such as fences, paving, vapor extraction, vapor barriers and environmental monitoring) or institutional controls (measures to keep receptors away from contamination, such as restrictive zoning of land use and deed restrictions).
- Established Levels - Established levels of contamination that, depending on site-specific conditions, may be MCLs, Level I RCLs or applicable Tier 1 SLs.

LIST OF TERMS AND DEFINITIONS, *continued*

- Executive Secretary - Executive Secretary (UST) of the Utah Solid and Hazardous Waste Control Board.
- Exposure - Contact of a human or other ecological organism with COCs.
- Exposure Assessment - The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration and route of exposure.
- Exposure Medium - The environmental medium through which an organism may be exposed to COC. Exposure media include the following: ***ambient air*** and ***indoor air*** that may be impacted by contaminant volatilization; ***groundwater*** that may be impacted by dissolved contaminants or contaminants leaching from soil to groundwater, and; ***soil*** that may be impacted by adsorbed contaminants.
- Exposure Pathway - The course or route COCs take from a contaminant source area to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to COCs. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure media (e.g., groundwater) is included. Exposure pathways involve transport of contamination through exposure media (air, groundwater and soil).
- Exposure Route - The course and manner in which COCs come in contact with an organism via ingestion, inhalation or dermal contact.
- Hazard Index - The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The hazard index is calculated separately for chronic, sub-chronic and shorter-duration exposures.
- Hazard Quotient - The ratio of a single substance exposure level over a specified period of time to a reference dose for that substance derived from a similar exposure period.
- Impacted Medium - The environmental media (i.e., air, soil, water) that has been impacted by COCs.
- Institutional Controls - Measures taken to keep receptors away from contamination. Typically, they involve restrictions on use or access to a site or facility to eliminate or minimize potential exposure to COCs, and may include, deed restrictions or restrictive land use zoning. Environmental monitoring is also considered an institutional control.
- Interim Corrective Actions - The course of action to mitigate fire and safety hazards and to prevent further migration of hydrocarbons in their vapor, dissolved or liquid phase.
- Maximum Contaminant Level (MCL) - Also known as Maximum Contaminant Limit (UACR311-211). A standard for drinking water established by the EPA under the Safe Drinking Water Act. The MCL is the maximum permissible level of COCs in water which is used as a drinking water supply. MCLs are recognized state-wide by the Divisions of Water Quality, Solid and Hazardous Waste, Drinking Water, and Environmental Response and Remediation.
- Monitoring - Conducting multiple sampling and other measurement rounds of environmental media at regularly-spaced intervals over a period of time. A minimum of one, two and five years of quarterly monitoring are required for Tier 2 Options 2, 3 and 4, respectively.
- Natural Attenuation - The verifiable natural reduction of a COC that occurs during transport away from the source area. It is the result of natural mechanisms such as microbial activity, diffusion, dispersion, adsorption, and chemical

LIST OF TERMS AND DEFINITIONS, *continued*

degradation. Natural attenuation, also known as Intrinsic Remediation, is usually verified through monitoring.

- Natural Attenuation Factor (NAF) - Represents the sum effect of various natural attenuation mechanisms. It is expressed as the ratio of the COC concentration at the source area divided by the COC concentration at the receptor or POE. The NAF includes Dilution Attenuation Factor (DAF) and Air Dispersion Factor (ADF).
- Other Applicable Standards - Cleanup levels that exist for media that may not include MCLs. Examples of other applicable standards are the Level I Recommended Cleanup Levels (RCLs) which apply only to soil, as shown in Utah Department of Health, BERR, 1990.
- Owner/Operator- Refers to the definition found in Utah Code Annotated, Section 19-6-403-(18). Operator means any person in control of or who is responsible on a daily basis for the maintenance of an underground storage tank that is in use for the storage, use, or dispensing of a regulated substance. "Owner" means: (a) in the case of an underground storage tank in use on or after November 8, 1984, any person who owns an underground storage tank used for the storage, use, or dispensing of a regulated substance; and (b) in the case of any underground storage tank in use before November 8, 1984, but not in use on or after November 8, 1984, any person who owned the tank immediately before the discontinuance of its use for the storage, use, or dispensing of a regulated substance.
- Parameter Input Data - Data values used for each parameter, such as "depth to groundwater."
- Permissible Exposure Limit (PEL) - An Occupational Safety and Health Administration (OSHA) limit of contaminant concentrations; from Title 29 of the Code of Federal Regulations, Part 21910, Subpart Z, General Industry Standards for Toxic and Hazardous Substances. PELs are based on 8-hour time-weighted average concentrations. The OSHA PELs are intended for acute rather than chronic exposure scenarios. They also apply to working conditions in which workers are knowingly exposed to contamination and must be OSHA-trained. The use of OSHA PELs is not permissible for Utah's Tier 2 risk assessments because exposure due to underground storage tank-related contamination is chronic. The PELs may be considered valid for use for sites which are currently under OSHA regulations for petroleum products.
- Point of Compliance (POC) - A location(s) selected within the source area where concentrations of the COCs must be at or below the determined target levels in media (e.g., soil, groundwater, air).
- Point of Exposure (POE) - The point at which an individual or population may come in contact with a COC originating from a site. For the purpose of this document, the Executive Secretary (UST) has determined that POEs shall include: water supply wells; surface water bodies; structures, and; underground utilities. For risk management purposes, the Executive Secretary (UST) has determined that the first down-gradient property line is to be considered a POE.
- RCL - "Recommended Cleanup Levels" for soil (UBERR, 1990) are non-risk-based, conservative concentrations for soil that, at the time UBERR, 1990 was published, were based on the environmental sensitivity of a site and the potential for leaching to groundwater for groundwater ingestion. The Level I RCLs only may now be applied.
- Reasonably Achieved - As used in Utah's Cleanup Standards Policy, Utah Admin. Code R311-211-5 (October 1995), reasonableness is based on consideration of impact or potential impact to public health and the environment, cost of cleanup and the available technology.
- Reasonably Anticipated Future Land Use - Likely future land use of a property or adjacent property given current use, local government planning, zoning, and representations by the current owner/operator.

LIST OF TERMS AND DEFINITIONS, *continued*

- Receptors - Persons, other ecological organisms such as fish and wildlife, water supply wells, surface water, sensitive habitats that are, or may be affected by a release. For the purpose of this document regarding risk management, the terms “receptor” and “Point of Exposure” may be used interchangeably.
- Reference Dose (RfD) - The toxicity value for evaluating non-carcinogenic effects resulting from exposures to chemicals of concern.
- Risk Assessment - An analysis of the potential for adverse health effects caused by COC to determine the need for remedial action. Also used to develop target levels where remedial action is required.
- Risk-Based Corrective Action (RBCA) - A decision-making process for the assessment and response to subsurface contaminants of concern from leaking underground storage tanks with the purpose of protecting human health and the environment.
- Risk-Based Screening Levels (RBSL) - Contaminant concentrations of chemical compounds for which toxicity data are available, and are formulated from the standard exposure and cross-media transport equations. RBSLs represent contaminant levels that are expected to be protective of receptors. RBSLs must be met at receptors, or points of exposure. Because RBSLs represent receptor concentrations, a Natural Attenuation Factor is not applied.
- Risk Reduction - The lowering or elimination of the level of risk posed to human health or the environment through initial response action, corrective action or environmental controls.
- Risk Management Goals - Measures or actions taken to ensure that exposure to COCs in excess of the TER does not occur.
- Screening Levels (SLs) - Contaminant levels that are based on general, non-site-specific assumptions and may be derived from the standard exposure equations or other methods which are not risk-based screening levels.
- Sensitive Habitat - Surface waters, wetlands, and habitats of threatened or endangered species.
- Site Assessment - The collection of data on groundwater quality and potential receptors, subsurface geology, hydrology, and site characteristics to determine the levels and extent of migration of the COC to support corrective action decisions.
- Site Classification - A qualitative evaluation of site-specific parameters such as the distance to receptors or other factors that affect the environmental sensitivity, and are determined from known or readily available information. Based on site classifications, initial response actions may need to be implemented throughout the RBCA process. Sites should be re-classified as actions are taken to resolve concerns or as better information becomes available.
- Site-Specific Cleanup Levels (SSCLs) - Risk-based levels for COCs at the source that are expected to be protective of receptors at some distance off-site or away from the source that are developed for a particular site under the Tier 2 Risk Assessment. Utah’s SSCLs are equivalent to ASTM’s SSTLs. For Utah’s Options 2 through 4, where the point of exposure may be at some distance from a point of compliance, the SSCLs equal the RBSL multiplied by a NAF. The SSCLs represent the source area (POC) contaminant concentrations that, when affected by a NAF, are expected to attenuate to the RBSL at the POE.
- Site-Specific Target Levels (SSTLs) - Concentrations of the constituents of concern that, if achieved throughout the

LIST OF TERMS AND DEFINITIONS, *continued*

source zone, will prevent exceedance of applicable risk limits at potential points of exposure (GSI, 1995). The SSTLs are equivalent to Utah's SSCLs.

- Slope Factor - A plausible upper-bound estimate of the probability of a response per unit of intake of a chemical over a lifetime of exposure to a particular level of a potential carcinogen.
- Source - The source of the COC, such as UST system or contaminated environmental media, which could lead to exposure, or the occurrence of increasing contaminant mass of COCs within or between environmental media. Sources may include USTs, product lines, dispensers, service bays, other UST appurtenances, free-product, or soil or groundwater with COC concentrations above Tier 1 criteria, calculated Tier 2 SSCLs or other applicable standards.
- Source Area - The location of the source (see above).
- Subsurface Investigation - The required investigation of a site to determine the extent and degree of the COCs, location of on-site and off-site receptors, and the potential for the COC to spread or cause an exposure to receptors.
- Surface Soil - Soil occurring between 0 feet and 3 feet below land surface. NOTE: Surface soil may also include *subsurface soil* that is or has the potential to be excavated or otherwise accessible.
- Subsurface Soil - Soil occurring at depths below 3 feet below land surface. NOTE: Subsurface soil may also be considered *surface soil* if it is or has the potential to be excavated or otherwise accessible.
- Target Excess Risk (TER) Limit - The probability of exceeding a 10^{-6} excess cancer risk for carcinogenic compounds or a hazard quotient of 1.0 for non-carcinogenic compounds.
- Tier 1 Criteria - Utah's (Utah Department of Environmental Quality, DERR, 1997) pre-determined screening levels for COCs that are based on: (1) general conservative regional site data that are characteristic of Utah's intermontane basins, established chemical property and chemical toxicity data, and; (2) a critical distance of 30 feet from the source area to subsurface utility lines, buildings and property lines, and a critical distance of 500 feet from the source area to water production wells and surface water bodies. Where applicable, cleanup levels may range from MCLs and Level I RCLs to Tier 1 criteria. See Appendix G for additional information regarding Tier 1 criteria.
- Tier 1 Evaluation - A risk-based analysis where non-site-specific values based on conservative exposure factors (RBSL), potential exposure pathways, and land use are evaluated to determine appropriate actions.
- Tier 2 Risk Assessment - A risk-based analysis applying the RBSL at the exposure point, development of the SSCL for potential exposure pathways based on site-specific conditions, and establishment of points of compliance.
- Transport Mechanism - The method of movement of COC through the environment. The transport mechanisms for contaminants include: volatilization and dust transport of surface soils in the air exposure pathway; volatilization for subsurface soil and groundwater in the air exposure pathway; leaching to groundwater and groundwater flow in the soil-leaching-to groundwater pathway; groundwater flow in the groundwater pathway, and; direct dermal contact in the soil exposure pathway.
- 95% Upper Confidence Limit (UCL) - 95% of the UCL of the arithmetic mean.

LIST OF ACRONYMS AND ABBREVIATIONS

ADF	Air Dispersion Factor
AFCEE	Air Force Center for Environmental Excellence
AL	Action Level
AMP	Alternate Monitoring Point
ASTM	American Society for Testing Materials
BERR	Utah Bureau of Environmental Response and Remediation
Board	Utah Solid and Hazardous Waste Control Board
BTEXN	Benzene, Toluene, Ethylbenzene, Xylenes, Naphthalene
CAP	Corrective Action Plan
CAS	Chemical Abstract Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter(s)
cm ³	cubic centimeter
COC	Constituent of Concern or Contaminant of Concern
CFR	Code of Federal Regulations
DAF	Dilution-Attenuation Factor
DERR	Utah Division of Environmental Response and Remediation
EPA	United States Environmental Protection Agency
ft	feet
ft ²	square feet
ft ³	cubic feet
g	gram(s)
GSI	Groundwater Services, Incorporated
GW	Groundwater
HEAST	Health Effects Assessment Summary Table
HI	Hazard Index

LIST OF ACRONYMS AND ABBREVIATIONS, *continued*

HQ	Hazard Quotient
ID	Identification
IRIS	Integrated Risk Information System
kg	kilogram(s)
L	Liter(s)
LEL	Lower Explosive Limit
LUST	Leaking Underground Storage Tank
m	meter(s)
m ³	cubic meter(s)
MCL	Maximum Contaminant Level or Maximum Contaminant Limit
mg	milligram(s)
mL	milliliter(s)
MTBE	Methyl-tert-butyl-ether
NAF	Natural Attenuation Factor
NAPL	Non-Aqueous Phase Liquid
NFA	No Further Action
No.	Number
O/O	Owner/Operator
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PEL	Permissible Exposure Limit
PIRI	Partners in RBCA Implementation
POC	Point of Compliance
POE	Point of Exposure
PST	Petroleum Storage Tank

LIST OF ACRONYMS AND ABBREVIATIONS, *continued*

RAP	Risk Assessment Proposal
RBCA	Risk-Based Corrective Action
RBSL	Risk-Based Screening Level
RCL	Recommended Cleanup Level
RfC	Reference Concentration
RfD	Reference Dose
RME	Reasonable Maximum Exposure
SCEM	Site Conceptual Exposure Model
sec	second
SF	Slope Factor
SIR	Subsurface Investigation Report
SL	Screening Level
SSCL	Site-Specific Cleanup Levels
SSTL	Site-Specific Target Levels
TER	Target Excess Risk
THQ	Target Hazard Quotient
TPH	Total Petroleum Hydrocarbons
TPHCWG	Total Petroleum Hydrocarbons Criteria Working Group
TRPH	Total Recoverable Petroleum Hydrocarbons
ug	microgram(s)
UAC	Utah Administrative Code
95% UCL	95% of the Upper Confidence Limit
Unann.	Unannotated
UST	Underground Storage Tank
yd ³	cubic yards
#	Number

I.0 Introduction

Utah's Department of Environmental Quality, Division of Environmental Response and Remediation (Utah Department of Environmental Quality, DERR), Leaking Underground Storage Tank (LUST) Section has developed a process to evaluate risks to human health and the environment resulting from petroleum contamination from LUSTs. This process is intended to address cleanup when maximum contaminant levels (MCLs) or other applicable cleanup standards cannot reasonably be achieved and is based on Utah Administrative Code R311-211, *Corrective Action Cleanup Standards Policy-UST and CERCLA Sites*, referred to throughout this document as "Cleanup Standards Policy." A copy of the Cleanup Standards Policy is provided in Appendix F. Utah's risk assessment process is derived from, and is consistent with, the United States Environmental Protection Agency's (EPA) Office of Solid Waste and Emergency Response (OSWER) Directive 9610.17 (February 24, 1994) ("EPA Directive" entitled *Use of Risk-Based Decision-Making in UST Corrective Action Programs*). The EPA Directive references the ASTM *Standard Guide for Risk-Based Corrective Action (RBCA) Applied at Petroleum Release Sites* (ASTM, 1995) which identifies and describes one method of evaluating the risk to human health and the environment posed by multiple constituents in petroleum-contaminated soil, groundwater and air.

The ASTM (1995) document provides guidance for evaluating risks at petroleum release sites using a three-tiered approach. The first tier (Tier 1) is a screening process that uses only general hydrogeologic information and conservative assumptions to ensure protection of potential receptors. The second and third tiers require increasingly more accurate site-specific data, as well as increasingly sophisticated contaminant fate and transport modeling to achieve greater accuracy and certainty in evaluating risks to receptors. The ASTM (1995) document contains the mathematical exposure equations for calculating risk-based screening levels (RBSLs) for a specified target excess risk (TER) limit.

Utah has generally adopted the ASTM (1995) method but has modified it into a two-tiered approach for performing risk assessments. Utah's method is designed to provide systematic and consistent determinations of risk to potential receptors in accordance with the Cleanup Standards Policy. Like the ASTM (1995) approach, Utah's two-tiered approach requires increasingly more accurate site-specific data and increasingly complex transient contaminant fate and transport modeling with each option upgrade in order to achieve greater accuracy and certainty in evaluating risks to receptors. Table I-1 compares Utah's RBCA approach to ASTM's, and to Groundwater Services, Inc.'s spreadsheet system that was developed for use with the ASTM RBCA approach for petroleum release sites (GSI, 1995).

I.1 Organization of this Document

This introduction provides a background and an overview of Utah's LUST corrective action process. The remaining sections and appendices in this document include the following:

- Section 1: Step-by-step guidelines for implementation of Utah's LUST corrective action process.
- Section 2: Step-by-step guidelines for implementation of the optional Tier 2 Risk Assessment.
- Section 3: Data evaluation and reporting procedures to be employed in the optional Tier 2 Risk Assessment.
- Section 4: References cited within this document.
- Appendix A: Tier 2 Risk Assessment worksheets.
- Appendix B: Tier 2 Risk Assessment site-specific data requirements and attachments.
- Appendix C: Tier 2 Risk Assessment calculations and modeling results.
- Appendix D: Guidelines for preparation of a Subsurface Investigation Report.
- Appendix E-1: Guidelines for preparation of a Corrective Action Plan (CAP).
- Appendix E-2: Guidelines for preparation of a Risk Assessment Proposal (RAP).
- Appendix F: Utah's Cleanup Standards Policy.
- Appendix G: Establishing cleanup standards using Utah's Tier 1 screening criteria.

Table I-1: Comparison of Risk-Based Corrective Action Terminology

	Tier 1	Tier 2			
		Option 1	Option 2	Option 3	Option 4
Utah DERR/ LUST	<ul style="list-style-type: none"> Non-site-specific <i>SLs</i> for <i>source area</i>^a for <i>select exposure pathways</i>. <i>Required TER at receptors</i>. <i>Allowable 10⁻⁴ SLs at source area when receptors are ≥30 feet from source</i>. Exposure equations pre-solved; <i>SLs based on general conservative assumptions</i>. 	<ul style="list-style-type: none"> Site-specific <i>cleanup levels (SSCLs)</i> = RBSL with no NAF. <i>Required TER at receptors</i>. Solve exposure/transport equations. On-site receptors evaluated. 	<ul style="list-style-type: none"> Site-specific <i>cleanup levels (SSCLs)</i> = RBSL X NAF. <i>Required TER at receptors</i>. Solve exposure/transport equations. On-site & off-site receptors evaluated. 	<ul style="list-style-type: none"> Site-specific <i>cleanup levels (SSCLs)</i> = RBSL X NAF. <i>Required TER at receptors</i>. Solve exposure/transport equations. On-site & off-site receptors evaluated. <i>Transient analytical modeling required</i> 	<ul style="list-style-type: none"> Site-specific <i>cleanup levels (SSCLs)</i> = RBSL X NAF. <i>Required TER at receptors</i>. Solve exposure/transport equations. On-site & off-site receptors evaluated. <i>Transient analytical & numerical modeling required</i>.
ASTM (1995)	<ul style="list-style-type: none"> Non-site-specific <i>RBSLs</i> for <i>receptors</i>^b for <i>applicable exposure pathways</i>. TER risk management decision and agency-specific. Exposure equations pre-solved; <i>RBSLs based on general conservative assumptions</i>. 	<ul style="list-style-type: none"> Site-specific <i>target levels (SSTLs)</i>. <i>TER for receptors is agency-specific</i>. <i>Cost of achieving Tier 1 RBSLs compared to cost of performing Tier 2.</i> 			<ul style="list-style-type: none"> Site-specific <i>target levels (SSTLs)</i>. <i>TER for receptors is agency-specific</i>. Tier 3. <i>Cost of achieving Tier 2 SSTLs compared to cost of performing Tier 3.</i> May require complex modeling.
GSI (1995)	<ul style="list-style-type: none"> Non-site-specific <i>RBSLs</i> for <i>receptors</i>^b for <i>applicable exposure pathways</i>. TER risk management decision and agency-specific. Exposure equations pre-solved; <i>RBSLs based on general conservative assumptions</i>. 	<ul style="list-style-type: none"> Site-specific <i>screening levels (SSSLs)</i> = RBSL with no NAF. On-site receptors evaluated. 	<ul style="list-style-type: none"> Site-specific <i>target levels (SSTLs)</i> = RBSL X NAF. On-site & off-site receptors evaluated. 	<ul style="list-style-type: none"> Site-specific <i>target levels (SSTLs)</i> = RBSL X NAF. <i>Cumulative effects may be evaluated</i>. On-site & off-site receptors evaluated. 	<ul style="list-style-type: none"> Site-specific <i>target levels (SSTLs)</i> = RBSL X NAF. Tier 3. May require complex modeling. On-site & off-site receptors evaluated.

Differences are shown in italics

^a receptors or POE are *not* at the source

^b receptors or POE are at the source.

1.2 Use of Alternative Cleanup Standards in Utah's Underground Storage Tank (UST) Program

These guidelines require use of a TER limit of 10^{-6} cancer risk for carcinogenic compounds and a hazard quotient of 1.0 for non-carcinogenic compounds. These levels are collectively call “the TER” throughout these guidelines.

Following elimination by removal or control of contaminant sources, the Cleanup Standards Policy provides that cleanup standards shall be MCLs for chemicals in water, the TER for chemicals in any other media, air quality standards for air as established under the Federal Clean Air Act, and other applicable standards such as Level I Recommended Cleanup Levels (RCLs) for soil (Utah Department of Health, 1990). However, the Cleanup Standards Policy recognizes that, following source elimination, cleanup to MCLs or other applicable standards may not always be reasonably achievable. In those cases, cleanup standards including numerical, technology-based, risk-based standards, or any combination of those standards, may be used to establish cleanup levels above the minimum cleanup standards for the remaining contamination on a case-by-case basis.

The Cleanup Standards Policy requires evaluation of the following criteria:

- Source elimination through removal or control;
- Current or potential impact of the contamination on public health;
- Current or potential impact of the contamination on the environment;
- Economic considerations and cost-effectiveness of cleanup options, and;
- Technology available for use in cleanup.

In assessing the evaluation criteria of Section R311-211-3, the following factors have to be considered:

- Quantity of materials released;
- Mobility, persistence and toxicity of materials released;
- Exposure pathways;
- Extent of contamination and its relationship to present or potential surface and groundwater locations, and uses;
- Type and levels of background contamination, and;
- Other relevant standards and factors as determined appropriate by the Utah Solid and Hazardous Waste Control Board (2 Utah Administrative Code R311-211-5(c)).

When establishing cleanup levels above the minimum standards, levels of contamination in groundwater, surface water, soil or air will not be allowed to degrade beyond the existing contaminant levels determined through appropriate monitoring or the use of other data accepted by the Board or the Executive Secretary (UST) as representative (2 Utah Admin. Code R311-211-4 and -5).

Initially, a Tier 1 evaluation, or screening analysis, is performed. Tier 1 is described in the DERR's *Guidelines for Utah's Tier 1 Risk-Based Corrective Action* (Utah Department of Environmental Quality, DERR, 1997). The Tier 1 evaluation is a screening process that uses general, Utah-specific hydrogeologic data and standard exposure assumptions to estimate maximum allowable contaminant concentrations, called Tier 1 screening levels (SLs) at the source area. These source area SLs are expected to attenuate to MCLs or other applicable cleanup standards within critical distances from the source area. Critical distances are 30 feet to utility lines, buildings and property lines, and 500 feet to water wells and surface water (Utah Department of Environmental Quality, DERR, 1997). If Tier 1 SLs are exceeded or if receptors are located within the critical distance of the source area, the Owner/Operator has the option to clean up to applicable standards or perform a Tier 2 Risk Assessment to determine if receptors are protected to MCLs, the TER, or other applicable standards. The risk assessment indicates the contaminant concentrations that must be achieved to ensure protection of receptors to the TER or applicable MCLs. The results of a risk assessment may indicate that

cleanup or source elimination are necessary to ensure protection of receptors in accordance with the Cleanup Standards Policy.

A flow chart of Utah's LUST corrective action process, including Tier 1, is shown in Figure 1-1. A flow chart of Utah's Tier 2 risk assessment process is shown in Figure 2-1. Each step in Figures 1-1 and 2-1 is described in detail to provide users with consistency and accuracy when managing LUST sites and conducting a risk assessment. The procedures and format for the Tier 2 Risk Assessment are provided in Section 3 of this document.

1.3 Optional Tier 2 Risk-Based Evaluation

As shown in Figure 1-1 (Utah's LUST Corrective Action Process), if the results of a Tier 1 Evaluation show Tier 1 criteria to be exceeded or not applicable (Step 1.7), DERR will require the Owner/Operator to complete a Subsurface Investigation to determine soil and groundwater impacts and associated exposure pathways. Following submittal of the Subsurface Investigation Report (see Step 1.9), the Owner/Operator may choose to either: (1) prepare a Corrective Action Plan (CAP) and proceed with corrective action measures subject to DERR approval of the CAP, or; (2) submit a Risk Assessment Proposal (RAP) and propose to conduct a Tier 2 Risk Assessment to further define corrective action requirements.

For sites proceeding directly with the CAP, Steps 1.15 through 1.22 on Figure 1-1 address requirements for CAP implementation, verification and case closure. If a RAP is approved by the DERR, the Owner/Operator must complete the additional site evaluation steps identified on Figure 2-1 and described in Section 2 of this document. As shown on Figure 2-1, the Tier 2 Risk Assessment involves four optional assessment levels, designated Options 1 through 4, for developing Site-Specific Cleanup Levels (SSCLs) for the source area. Each successively higher option requires more detailed site-specific data, and the use of increasingly sophisticated modeling methods to refine the SSCL calculations.

The Owner/Operator chooses how far to proceed through Tier 2 Options 1 through 4 based on technical and economic considerations, and concludes the Tier 2 Risk Assessment after deriving appropriate and protective SSCL values. These SSCL values are then compared to constituent concentrations measured in site soils and groundwater to define the scope of any necessary corrective actions. Should SSCL values be exceeded for any complete exposure pathways, the Owner/Operator must submit a CAP identifying appropriate cleanup methods for the affected media.

1.4 Risk Management Requirements

If the Owner/Operator elects to conduct a Tier 2 Risk Assessment, a CAP may need to be developed and implemented to achieve applicable risk management goals. If the Owner/Operator chooses to proceed directly with the CAP submittal (see Step 1.10), the CAP must target specific areas of soil and groundwater contamination found to exceed Tier 1 criteria (if applicable), or soil Level I RCLs and groundwater MCLs (if Tier 1 screening levels are not applicable). If a Tier 2 Risk Assessment is completed, the CAP should address affected media exceeding the calculated SSCLs.

The Tier 2 Risk Assessment, as described in this document, does not represent a baseline assessment of actual risks posed to public health or the environment. Rather, given the conservative nature of the Tier 2 Risk Assessment, exceedance of Tier 2 SSCLs serves only to trigger evaluation of necessary corrective action measures. If affected soils or groundwater do not exceed the applicable risk-based SSCLs, corrective action may not be necessary.

For each exposure pathway posing a potential concern (as identified in the Site Conceptual Exposure Model), the proposed CAP (see Step 2.22) must achieve minimum performance standards. These standards are protective criteria that will reduce risk posed to current and potential receptors. For underground utilities, such performance standards entail practical measures to prevent property damage, explosion or off-site contaminant migration. For human exposure pathways, the remedy must serve to prevent human exposure to harmful levels of COCs.

In accordance with Utah Administrative Code R317-1-1.32 and Utah Code Annotated 19-5-102 et. seq., the State of Utah must protect all groundwaters of the state. Therefore, for the purpose of risk management, the Executive Secretary (UST) has determined that all groundwater, including currently non-potable sources, be considered a potential receptor or point of exposure, and must be adequately protected as a potential resource of future drinking water.

Appropriate measures to achieve the remedy performance standards will depend on the immediacy of the potential exposure. Engineering controls involving active removal or treatment measures may be required for *current* on-going exposure scenarios, whereas passive, natural attenuation remedies may suffice for *potential future* exposure. Further discussion of corrective action evaluation and selection procedures for the CAP is provided in Section 2 of this guidance document (see Step 2.22).

1.5 Confirmation Sampling and Compliance Monitoring Requirements

Upon completion of the Tier 2 Risk Assessment or CAP, the Owner/Operator must submit information verifying that applicable performance or corrective action standards have been achieved, as follows:

- For corrective action involving soil or groundwater removal and/or treatment, verification sampling and testing is required to confirm that constituent concentrations remaining in place do not exceed applicable cleanup standards;
- For corrective measures involving use of environmental controls, information must demonstrate that the completed controls are adequate to prevent human exposure to harmful levels of COCs;
- For soils, confirmation sampling may involve sampling and testing episodes as needed to confirm corrective action completion and to confirm remaining levels of contamination, and;
- For all groundwater corrective actions, confirmation sampling and compliance monitoring may involve multiple sampling episodes to verify stable contaminant plume conditions and satisfactory cleanup prior to case closure. As discussed in Steps 1.21 and 2.26 in this document, to demonstrate completion of groundwater remediation efforts, DERR may require multiple consecutive quarterly monitoring episodes confirming that constituent concentrations are less than or equal to applicable limits at specified monitoring points. DERR reserves the right to either shorten or expand this monitoring period based on consideration of site-specific conditions.

1.6 No Further Action Letter

If the DERR's review of information provided by the Owner/Operator confirms that performance standards and relevant cleanup levels have been satisfied, the Executive Secretary (UST) will issue a "no further action" letter to the site Owner/Operator. This "no further action" letter specifies that, based on the current site conditions and land use reported by the Owner/Operator, no further environmental site investigations or corrective actions will be required. However, if future evidence indicates the occurrence or spread of contamination at or emanating from the site which may cause a threat to human health and the environment, further corrective action may be required.

1.7 Petroleum Storage Tank (PST) Fund

For eligible release sites that qualify for funding from the Petroleum Storage Tank (PST) Fund, costs incurred by Owners/Operators while preparing and completing the Tier 2 risk assessment process will be reviewed on the following basis:

- Work Plans and Budgets for all expenses incurred beyond the standard deductible amount must be approved by the Executive Secretary (UST) prior to the work being started. This includes any work required to prepare a Risk Assessment Proposal (RAP).

- The Executive Secretary (UST) will review all submitted expenses and will determine if the work completed followed the approved Work Plans and Budgets, and if the expenses were customary, reasonable and legitimate in accordance with Utah Administrative Code R311-207.
- If the Executive Secretary (UST) determines that a risk assessment appears to be the most cost-effective option, the Owner/Operator should submit the RAP to the DERR project manager, whether or not the standard deductible has been met. This is to ensure that the cost involved with a Tier 2 Risk Assessment is the most reasonable and cost effective approach for the Owner/Operator and will be covered by the PST Fund. The RAP, which includes a cost feasibility analysis as directed by the DERR project manager, should be submitted as a proposed work plan for the Executive Secretary's (UST) review and approval prior to implementation.

1.0 Utah's LUST Corrective Action Process

The following procedures describe Utah's general corrective action process for LUST sites and correspond to the numbered steps shown in Figure 1-1.

Step 1.1: Release Reported to the DERR

The Owner/Operator is required to report to the DERR (phone 801-536-4100) petroleum releases from their facility within 24 hours of discovery, in accordance with Utah Administrative Code R311-202 (UST Technical Standards). The DERR completes a Release Report form (Utah Department of Environmental Quality, DERR, 1997, Tier 1 Appendix A) to record important information concerning the release and its impacts. The DERR project manager receiving the Release Report obtains as much information about the release as possible from the reporting party to assist the Owner/Operator in expediting abatement and cleanup of the contamination and proceeding with the Tier 1 screening process. The Release Report information includes the following:

- Owner information;
- Site location;
- Current land use at the site and surrounding neighborhood;
- The cause, source and detection methods of the release;
- Type and amount of contaminant released;
- Details concerning soil and groundwater contamination (concentrations and locations);
- Type and location of receptors;
- Measures taken to abate the release, and;
- The Owner's/Operator's PST Fund eligibility status.

Data supplied in the Release Report form are used to complete the Tier 1 Worksheet and enable the DERR to classify and prioritize sites efficiently and consistently. The more information that is known and reported, the more accurate the site classification and the degree of certainty concerning the threats to human health and the environment will be.

- If an emergency situation exists (potential explosion or vapor hazard, drinking water supply impacted, or other direct and immediate threats), the site is a Classification 1 and the Executive Secretary (UST) will require immediate corrective action to abate, control, or prevent threats to human health and the environment and risk to receptors.
- Sites for which little data are provided are considered Classification 2 (potentially exposed receptors).

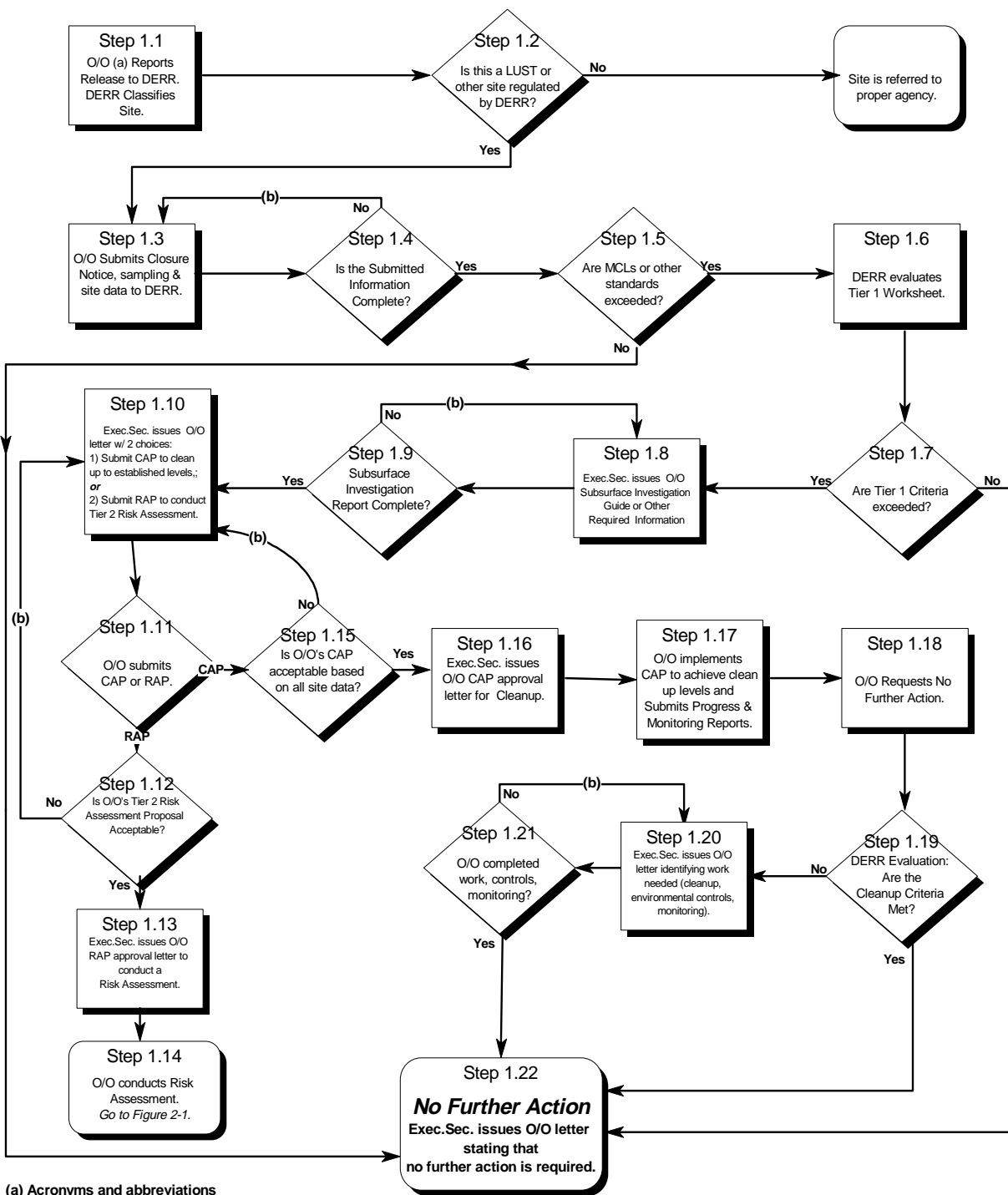
A more detailed explanation of the site classification process can be found in Appendix B of the DERR's Tier 1 process (Utah Department of Environmental Quality, DERR, 1997). Site classification is a dynamic process that may change as new information is submitted to the DERR.

GO TO STEP 1.2 to determine the regulatory status of the reported release.

Step 1.2: Is the Release from a LUST or Other Site Regulated by the DERR?

The DERR determines if a reported petroleum release is caused by a LUST that is subject to regulation by the Utah Underground Storage Tank Act, Utah Code Unann.§§ 19-6-401 to -427.

Figure 1-1: Utah's LUST Corrective Action Process



(a) Acronyms and abbreviations

CAP	Corrective Action Plan
DERR	Utah Division of Environmental Response and Remediation
Exec.Sec	Executive Secretary (UST)
LUST	Leaking underground storage tank
MCLs	Maximum Contaminant Levels
O/O	Owner or operator of a LUST
RAP	Risk Assessment Proposal

(b) DERR issues O/O correspondence identifying information needed.

The LUST program currently provides oversight of aboveground storage tank releases in accordance with “Memorandum of Understanding with the Utah Division of Water Quality (Utah Department of Environmental Quality, DERR, 1996).

Yes: GO TO STEP 1.3 if the release is regulated under the UST program.

No: If the release is not regulated under the UST program, the DERR refers the site to the proper regulatory agency. These may include the Utah Division of Water Quality (phone 801-538-6146), Utah Division of Solid and Hazardous Waste (phone 801-538-6170), local health department or other appropriate agency.

Step 1.3: *Owner/Operator Submits Closure Notice, Sampling Data and Site Data*

When the Owner/Operator has closed a UST system (removal or in-place closure), they are required to submit a Closure Notice within **90 days** of the UST closure. The Closure Notice contains information regarding on-site contaminant concentrations, location and depth of closure samples, analytical results of closure samples, distance to receptors and land use. This information enables the DERR to determine if MCLs, the TER or other applicable standards for soil (Utah Department of Health, BERR, 1990) are exceeded. Other important site data may be obtained from the Closure Plan, Closure Inspection Report, sampling and monitoring data, historical data, site maps, and other related reports.

GO TO STEP 1.4 where the DERR determines if the submitted information is complete.

Step 1.4: *Is the Submitted Information Complete?*

The DERR determines if the submitted information is complete and sufficient for determining if MCLs or other applicable standards are exceeded. ***Incomplete or deficient information may result in processing delays.*** Deficiencies in Closure Notices include failure to provide properly scaled site maps, distance to receptors, depth to groundwater, and location of all subsurface utility lines, buildings and property lines.

Yes: GO TO STEP 1.5 if the information submitted by the Owner/Operator is complete.

No: GO TO STEP 1.3 if the Owner/Operator submits incomplete or insufficient data. The Executive Secretary (UST) will contact the Owner/Operator and identify what additional information is required.

Step 1.5: *Are the Maximum Contaminant Levels or Other Applicable Standards Exceeded?*

The DERR reviews all information submitted and determines if the MCLs for groundwater or applicable cleanup standards for soil are exceeded.

Yes: GO TO STEP 1.6 if the DERR determines that the MCLs for groundwater or if applicable cleanup standards for soil *are* exceeded.

No: GO TO STEP 1.22 for the no further action process if the DERR determines that the MCLs for groundwater or applicable cleanup standards for soil *are not* exceeded.

Step 1.6: *The DERR Evaluates the Tier 1 Worksheet*

If the MCLs or other applicable standards are exceeded, the DERR completes a Tier 1 Worksheet (Utah Department of Environmental Quality, DERR, 1997 and Appendix G) using the information in the Closure Notice or other reports. The Tier 1 Worksheet may be completed by the Owner/Operator or owner’s representative. The Tier 1 Worksheet provides a format to simplify, standardize and expedite the process for reporting and evaluating the nature of the release, locations of receptors and exposure pathways to determine potential impact to receptors.

The DERR completes and/or evaluates the Tier 1 Worksheet to ensure that it is accurate and provides sufficient information to classify the site, locate all receptors, and compare contaminant concentrations at the source to Tier 1 screening levels. The Tier 1 screening levels may only be used if the worksheet is completed and all Tier 1 criteria are met.

GO TO STEP 1.7 where the DERR determines if Tier 1 criteria are exceeded.

Step 1.7: Are the Tier 1 Criteria Exceeded?

The DERR determines if Tier 1 criteria are exceeded based on the completed Tier 1 Worksheet. Tier 1 criteria consist of the SLs and the critical distances from the source area to receptors. The Tier 1 SLs represent contaminant concentrations in soil and groundwater at the source area that are expected to be protective of human health and the environment to the applicable MCLs, the TER, or other applicable standards if there are no receptors within the critical distances (see Appendix G regarding the establishment of cleanup levels using Tier 1 screening criteria). The Tier 1 SLs may be applied only when the Tier 1 criteria are met and documented by a completed Tier 1 Worksheet.

Yes: GO TO STEP 1.8 if the Tier 1 criteria *are* exceeded. The Executive Secretary (UST) issues the Owner/Operator a Subsurface Investigation Report guide to help the Owner/Operator characterize the site and define the extent and degree of contamination.

No: GO TO STEP 1.22 if Tier 1 criteria *are not* exceeded. The DERR may initiate the close-out procedure and, if approved by the Executive Secretary (UST), the Executive Secretary (UST) will issue the Owner/Operator a “no further action” letter.

Step 1.8: Executive Secretary (UST) Issues the Owner/Operator a Subsurface Investigation Report Guide

The Executive Secretary (UST) issues the Owner/Operator a Subsurface Investigation Report guide, a copy of which is included in Appendix D. The Subsurface Investigation Report guide outlines the requirements and schedules for completing a subsurface investigation. The Owner/Operator completes the subsurface investigation by defining the extent and degree of the subsurface soil and/or groundwater petroleum contamination, locating and evaluating receptors and exposure pathways, and conducting abatement of the release, as needed. The information gained from a subsurface investigation is used to determine current and potential exposure pathways and risks to receptors, and to determine cleanup levels that are expected to be protective of receptors.

The Owner/Operator submits the Subsurface Investigation Report to the DERR within **90 days** of being issued the Subsurface Investigation Report guide.

GO TO STEP 1.9 for the DERR's review of the Subsurface Investigation Report.

Step 1.9: Is the Subsurface Investigation Report Complete?

The DERR reviews the Owner's/Operator's Subsurface Investigation Report for completeness concerning the extent and degree of contamination, location of receptors, and exposure media and pathways. Deficiencies of Subsurface Investigation Reports include failure to define the extent and degree of contamination in all affected media, identify all receptors, sample all actually or potentially affected media, and provide complete site maps and cross-sections.

Yes: GO TO STEP 1.10 if the information provided by the Subsurface Investigation Report *is* complete.

No: GO TO STEP 1.8 if the Subsurface Investigation Report *is not* complete. The Executive Secretary (UST) then issues correspondence to the Owner/Operator identifying required information and/or work that is needed at the site.

Step 1.10: Executive Secretary (UST) Issues the Owner/Operator Corrective Action Plan Guide

After the Subsurface Investigation has been accepted, the Owner/Operator may be responsible for submitting a CAP to perform cleanup to established levels (MCLs, Level I RCLs, or other applicable standards, e.g., Tier 1 criteria) or a RAP to develop SSCLs and conduct a Tier 2 Risk Assessment. The Executive Secretary (UST) may then issue the Owner/Operator a letter with guidance that outlines the requirements for either the CAP or RAP. The letter will establish and include cleanup levels for Owners/Operators that choose to submit a CAP. The CAP and RAP guides are shown in Appendices E-1 and E-2, respectively.

- A CAP may be appropriate for those sites where the need for cleanup exists and the appropriate type of corrective action for cleanup is readily apparent.
- For those sites where the potential cost of the corrective action and other applicable factors warrant the need for further evaluation, a Tier 2 Risk Assessment may be appropriate to evaluate the need for corrective action. The purpose of the Tier 2 Risk Assessment is to determine if the complete exposure pathways pose a potentially harmful exposure that requires corrective action. The SSCLs that are developed using the Tier 2 Risk Assessment process serve as threshold concentrations to identify those portions of the affected soil and groundwater that may require corrective action.

Whichever approach is selected by the Owner/Operator (CAP or RAP), the goal is to ensure protection of human health and the environment.

Corrective Action Plan

The CAP must evaluate all appropriate and applicable corrective action technologies based upon the cost-effectiveness, technological feasibility, and ability of each technology to protect human health and the environment. Design and construction details are required for the selected corrective action, along with other requirements outlined in Utah Administrative Code R311-202, Section 280.66. All of those requirements are included in the CAP guide in Appendix E-1. The Owner/Operator is required to submit all information identified in the CAP guide provided in Appendix E-1 within **90 days** of receiving the guide. All CAPs must be reviewed and approved by the Executive Secretary (UST) prior to their implementation.

Following the DERR's review of the CAP, but prior to the Executive Secretary's (UST) final approval, the Owner/Operator is required to notify the potentially affected public of the proposed corrective action in accordance with R311-202, Section 280.67. Detailed guidance for public notice requirements can be found in the CAP guide.

Risk Assessment Proposal

As an alternative to performing cleanup to established standards, the Owner/Operator may propose to conduct a Tier 2 Risk Assessment to develop SSCLs at the source area for soil and groundwater. The first step of this approach is the preparation of a RAP in conformance with the guidelines in Appendix E-2. The RAP is due within **90 days** of receiving the guide.

The purpose of the RAP is to ensure that a Tier 2 Risk Assessment appears to be the most feasible and cost-effective approach for Owners/Operators to meet the criteria outlined in Utah's Cleanup Standards Policy (Utah Admin. Code R311-211). If the RAP is approved, the Owner/Operator may proceed with the Tier 2 Risk Assessment as outlined

in Figure 2-1, Section 2 and Section 3 of this document. Upon completion of the Tier 2 Risk Assessment, a CAP must be provided for those areas of affected soil and/or groundwater that exceed the SSCLs. If the RAP is not approved, the Owner/Operator is required to submit a CAP to meet previously established cleanup levels or other applicable standards.

For the RAP, the Owner/Operator must submit information confirming compliance with the following requirements:

- Source elimination: The source of the contamination must be eliminated by removal or control as needed to prevent any further release into the environment.
- Data requirements: Site-specific information needs to be collected and documented to meet the Tier 2 Risk Assessment data requirements specified in Worksheet #2 of Appendix A.
- Exposure control: A site exposure evaluation must be made by completing a Site Conceptual Exposure Model (SCEM) (Worksheet #1 of Appendix E-2) and implementing interim measures as needed to address any actual or short-term human or ecological exposure to contaminants at the release site. The SCEM is useful for identifying sources of contamination, contaminant transport mechanisms, exposure pathways, potential receptors and cleanup options for complete exposure pathways. The SCEM identifies the combination of factors that could result in complete exposure pathways and potential routes of exposure that could result in uptake of the contaminants. Upon completion of the SCEM, if an exposure pathway is considered *incomplete*, the Owner/Operator must provide a brief written explanation that describes why the pathway is not complete.
- Corrective action technology and cost evaluation: The Owner/Operator must document that corrective action based on Tier 2 SSCLs is likely to be significantly more cost-effective and reasonable than cleanup to established standards. This evaluation is based on consideration of initial capital costs, sampling costs, operating and maintenance costs, for technically feasible corrective action methods.

GO TO STEP 1.11 for the CAP or RAP submittal.

Step 1.11: The Owner/Operator Submits a Corrective Action Plan or a Tier 2 Risk Assessment Proposal.

- GO TO STEP 1.12 if the Owner/Operator submits a RAP.
- GO TO STEP 1.15 if the Owner/Operator submits a CAP.

Step 1.12: Is the Owner's/Operator's Risk Assessment Proposal Acceptable?

The DERR evaluates RAPs based on the RAP guidelines in Appendix E-2. Specifically, this includes the appropriateness and accuracy of the SCEM, the RAP's discussion and comparison of all appropriate and applicable cleanup methods, the technical and economic feasibility of each cleanup method, the current and potential impact of the contamination to public health and the environment, exposure pathways, and the locations of receptors.

- If the RAP indicates that conducting a risk assessment is reasonable and capable of ensuring that receptors are adequately protected to applicable MCLs, the TER or other applicable standards in accordance with the Cleanup Standards Policy, the Executive Secretary (UST) may then approve the RAP.
- If the RAP is deficient in providing the required information, the Executive Secretary (UST) will issue the Owner/Operator correspondence identifying the deficient information. Deficiencies in RAPs include failure to adequately identify, evaluate and document all contaminated media, and complete exposure pathways and receptors.

Yes: GO TO STEP 1.13 if the Executive Secretary (UST) approves the RAP.

No: GO TO STEP 1.10 the Executive Secretary (UST) issues the Owner/Operator a letter that identifies deficiencies in the RAP or specify that a CAP is required.

Step 1.13: Executive Secretary (UST) Issues RAP Approval Letter to Owner/Operator to Conduct a Tier 2 Risk Assessment

The Executive Secretary (UST) issues the Owner/Operator a letter that approves the RAP to conduct a risk assessment. The approval letter may identify any contingencies or information needed, and a schedule for submitting progress and monitoring reports.

GO TO STEP 1.14 for the Tier 2 Risk Assessment Process.

Step 1.14: Owner/Operator Conducts a Tier 2 Risk Assessment

Owners/Operators may conduct a Tier 2 Risk Assessment by following the procedures shown in Figure 2-1 and described in Section 2 and Section 3 of this document.

GO TO SECTION 2 AND SECTION 3 OF THIS DOCUMENT.

Step 1.15: Is the Owner's/Operator's Corrective Action Plan Acceptable?

CAPs are reviewed and evaluated by the DERR and approved based on the CAP's discussion and comparison of all applicable and appropriate cleanup methods, the technical and economic feasibility of each method, and the ability of the cleanup method selected to adequately protect current and potential receptors to MCLs, the TER or other applicable standards in accordance with the Cleanup Standards Policy. If the submitted CAP is deficient in detailing the required information, the Executive Secretary (UST) will issue the Owner/Operator correspondence identifying the deficient information. Deficiencies include permit issues, public notification, technical specifications and engineering designs, provisions for analyzing specific constituents of concern, and confirmation sampling and monitoring plans.

Yes: GO TO STEP 1.16 if the Owner/Operator submits an acceptable CAP for the DERR's review. The Executive Secretary (UST) will issue a letter to the Owner/Operator approving implementation of the CAP.

No: GO TO STEP 1.10 if the requirements for preparing a CAP have not been met. The Executive Secretary (UST) will issue the Owner/Operator correspondence identifying deficiencies in the submitted CAP.

Step 1.16: Executive Secretary (UST) Issues Letter to Owner/Operator Approving the Corrective Action Plan

The Executive Secretary (UST) issues the Owner/Operator a letter that approves the CAP. The CAP approval letter may identify any contingencies or information needed, required cleanup levels, and a schedule for submitting progress and monitoring reports.

GO TO STEP 1.17 to implement the CAP and submit progress and monitoring reports.

Step 1.17: Owner/Operator Implements the Corrective Action Plan to Achieve Established Cleanup Levels and Submits Progress and Monitoring Reports

The Owner/Operator is responsible for implementing the CAP for the approved cleanup technology and for submitting progress and monitoring reports to the DERR in accordance with the approved CAP. Progress and monitoring reports enable the DERR to determine the progress and effectiveness of cleanup.

GO TO STEP 1.18 for the no further action request.

Step 1.18: Owner/Operator Requests No Further Action

After cleanup levels are achieved, the Owner/Operator may request that no further action be taken. Progress and monitoring reports and other documentation must be submitted to the DERR outlining how cleanup levels were achieved.

GO TO STEP 1.19 where the Executive Secretary (UST) determines if further action is required based on the Cleanup Standards Policy.

Step 1.19: DERR Evaluation: Are the Evaluation Criteria in the Cleanup Standards Policy Met?

The DERR evaluates the progress and monitoring reports based on the Cleanup Standards Evaluation Criteria required by the Cleanup Standards Policy. Those criteria are:

- Source elimination through removal or control;
- Current or potential impact of the contamination on public health;
- Current or potential impact of the contamination on the environment;
- Economic considerations and cost-effectiveness of cleanup options, and;
- Technology available for use in cleanup.

Yes: GO TO STEP 1.22 if cleanup has been completed, the Executive Secretary (UST) issues the Owner/Operator a “no further action letter.”

No: GO TO STEP 1.20 if cleanup has not been completed, the Executive Secretary (UST) issues the Owner/Operator a letter identifying further work needed such as continued cleanup, monitoring, or options for implementing voluntary environmental controls.

Step 1.20: Executive Secretary (UST) Issues the Owner/Operator a Letter Identifying Further Work Needed

If the requirements of the Cleanup Standards Evaluation Criteria have not been met, the Executive Secretary (UST) issues the Owner/Operator a letter identifying work needed to meet those requirements. The letter identifies the options available for closing the case file and achieving no further action. Available options generally include continuing cleanup to applicable standards, on-going monitoring, conducting a risk assessment, or implementing voluntary environmental controls. Forms of environmental controls may include:

- Flagging the site in the records of the DERR as closed with contamination in place;
- Creating and imposing land use restrictions or notices to be enforced by the Owner upon subsequent purchasers.
- Establishing an easement to retain access to the property for monitoring and cleanup purposes;
- Providing fencing or paving to physically restrict site access;
- Imposing land use and zoning restrictions, and;
- Requiring continued environmental monitoring.

The Owner/Operator may choose to submit a RAP to conduct a Tier 2 Risk Assessment to establish new cleanup

levels if the approved CAP is no longer cost-effective or technically capable of achieving the original cleanup levels. See Step 1.10 for RAP requirements. The Cleanup Criteria again must be evaluated and must demonstrate that new cleanup levels are protective of all receptors to applicable MCLs, the TER or other applicable Standards.

GO TO STEP 1.21 for the evaluation of whether activities at the site are complete.

Step 1.21: Has the Owner/Operator Completed Cleanup, Environmental Controls or Monitoring?

The Owner/Operator is responsible for completing appropriate work for achieving the cleanup levels and meeting the requirements of the Cleanup Criteria (see Step 1.19). The DERR evaluates all data to determine if the work performed is successful in meeting the requirements of the Cleanup Criteria. See Step 2.26 of this document for details concerning soil and groundwater compliance monitoring and confirmation sampling requirements.

Yes: GO TO STEP 1.22 if the Owner/Operator has completed the required work and the Cleanup Criteria are satisfied.

No: GO TO STEP 1.20 if the Owner/Operator has not completed the required work and the Cleanup Criteria are not satisfied in accordance with Step 1.19. The Executive Secretary (UST) issues the Owner/Operator correspondence stating that the case file cannot be closed out until the required work for achieving no further action is complete.

Step 1.22: No Further Action: Executive Secretary (UST) Issues Owner/Operator a No Further Action Letter

If the cleanup levels have been met and the Cleanup Criteria have been satisfied, the Executive Secretary (UST) of the Utah Solid and Hazardous Waste Control Board will issue a “no further action” letter to the Owner/Operator based on the current land use at the site. However, if future contamination is found at or emanating from the site, or if the use of the property changes such that there is an increased risk from the contamination left in place, further corrective action may be required.

2.0 Risk Assessment Process

2.1 Overview of Tier 2 Risk Assessment Process

Utah's Cleanup Standards Policy, which is included in Appendix F, provides Owners/Operators with the opportunity to derive site-specific, risk-based petroleum cleanup levels for LUST sites when:

- The source of contamination has been eliminated by removal or control, and;
- Maximum Contaminant Levels (MCLs) or other applicable standards cannot be reasonably achieved.

The risk-based cleanup levels must ensure that all receptors are protected to applicable MCLs, the TER or other applicable standards. Owners/Operators may derive risk-based SSCLs by evaluating all exposure pathways, identifying all complete exposure pathways, and solving the standard exposure and transport equations set forth in EPA (1989), ASTM (1995) and Appendix C.

Owners/Operators are advised that risk assessments do not necessarily secure closure of a case file, and may actually indicate that cleanup is necessary. Owners/Operators are cautioned that conducting a Tier 2 Risk Assessment inherently includes a willingness to accept the possibility that land use at a LUST site may be limited because of potentially complete exposure pathways.

Utah has developed the Tier 2 Risk Assessment process shown in Figure 2-1 to provide Owners/Operators with a systematic and standardized approach to conducting a site-specific risk assessment. The Tier 2 Risk Assessment process is modified from the ASTM (1995) document, and is a useful tool to help Owners/Operators derive risk-based SSCLs and meet the requirements of the Cleanup Standards Policy.

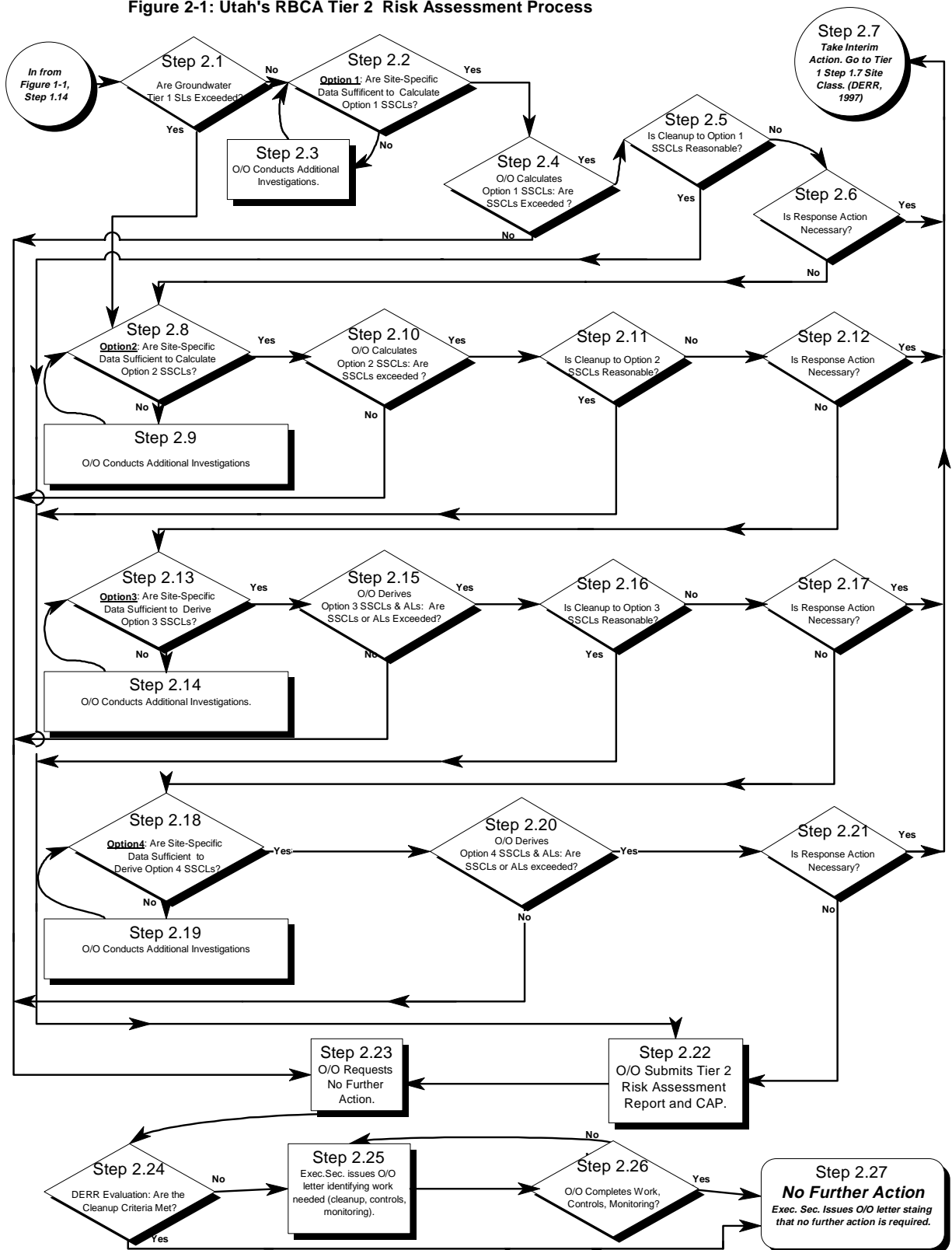
Utah's Tier 2 Risk Assessment process includes four options that, with each increasing option, increase in complexity and site-specific data requirements. The increased detail associated with each option increases the degree of certainty for protecting human health and the environment. Most Tier 2 Risk Assessment options require rigorous subsurface investigations to achieve increasing levels of confidence in deriving the risk-based SSCLs.

The Tier 2 Risk Assessment is a more complex process than a Tier 1 evaluation because Tier 2 is based on site-specific data and modeling rather than the general, conservative assumptions of Tier 1. Site-specific parameter values for Tier 2 are determined from the results of subsurface investigations. Parameters for which site-specific values are necessary are shown in Appendix A Worksheet #2 of this document. Site-specific parameter values may be based on field measurements or the permissible values listed in Worksheet #2 of Appendix A. Non-site-specific parameters that may not be varied from the default values are also shown in Worksheet #2, and include exposure parameters such as ingestion and inhalation rates, and enclosed space parameters. Chemical property and toxicity values are shown in Appendix C, Tables C-2 through C-5. The exposure and transport equations necessary for calculating SSCLs are shown in Appendix C, Table C-1.

To begin the Tier 2 Risk Assessment, the Owner/Operator uses site-specific parameter values (Appendix A, Worksheet #2) as input for the equations to calculate SSCLs (Appendix C, Table C-1). Tier 2 SSCLs are calculated by the Owner/Operator using the equations shown in Appendix C or commercially available spreadsheets.

The DERR accepts a 95% Upper Confidence Limit (UCL) or the maximum contaminant concentrations, whichever is lowest, for comparison to SSCLs. The 95% UCL depends on sample variability and number of samples collected.

Figure 2-1: Utah's RBCA Tier 2 Risk Assessment Process



If the on-site contaminant concentrations exceed the calculated cleanup levels, the Owner/Operator may either perform cleanup to the SSCLs or move to higher options in the Tier 2 Risk Assessment process to increase the level of accuracy of the risk assessment. The higher options require increasingly rigorous site data, but provide greater accuracy in deriving protective SSCLs and evaluating risk to receptors. The greater accuracy is largely achieved by using transient contaminant fate and transport modeling under Options 3 and 4 to further evaluate the calculated SSCLs and derive final SSCLs. The DERR uses the RBCA spreadsheet (GSI, 1995) to verify the calculations for deriving SSCLs. The DERR uses the following transient contaminant fate and transport models to verify the modeling results for Options 3 and 4:

- SOLUTE (Beljin, 1991);
- BIOSCREEN (Newell, et al., 1996);
- VLEACH (Ravi and Johnson, 1995), and;
- BIOPLUME (Rifai, et al., 1987).

The Owner/Operator may begin the Tier 2 Risk Assessment after the Executive Secretary (UST) approves the Owner's/Operator's Risk Assessment Proposal (RAP) which was discussed in Section 1, Steps 1.12 through 1.14. The Owner/Operator then follows the steps outlined in Figure 2-1 and described in detail in Sections 2 and 3 of this document.

2.2 Required Procedures for All Tier 2 Options

The goal of the Tier 2 Risk Assessment is to identify soil and groundwater source areas that could pose an unacceptable risk to public health or the environment under current or future land use conditions. The Tier 2 Risk Assessment is based on mandatory exposure assumptions involving exposure pathways, receptors, points of exposure, exposure factors, and others. Tier 2 Option 1 through Option 4 vary with regard to the contaminant fate-and-transport modeling methods to be employed for derivation of soil and groundwater SSCLs. However, all Tier 2 evaluations must conform to the general procedures and exposure assumptions summarized below.

Preliminary Exposure Pathway Evaluation and Required Response Actions

The goal of the corrective action process is to protect public health and the environment from impacts associated with exposure to harmful levels of constituents of concern (COCs). The Tier 2 Risk Assessment addresses several possible exposure pathways for contaminant migration from the source to a receptor via air, soil or groundwater under typical land use conditions. Exposure pathways are summarized in Table 2-1 of Section 2, and are illustrated on Figure A-1 in Worksheet #3 of Appendix A. For the Tier 2 Risk Assessment, the Owner/Operator evaluates the potential for each of the exposure pathways to be complete by evaluating the SCEM (Worksheet #3 of Appendix A). For each complete exposure pathway identified in Worksheet #3, SSCLs must be derived and compared to measured COC concentrations to determine the need for corrective action.

Pathways may be designated as incomplete *only* if site conditions meet the criteria specified in Worksheet #3, in Appendix A. For example, the surface soil exposure pathway (dermal contact, vapor/particulate inhalation) is considered incomplete if subsurface soil is so deep that it is not likely to be excavated and brought to the surface.

For exposure pathways that indicate either potential or current exposure, the Owner/Operator may need to implement interim measures to abate or control the exposure to human health and the environment. The Owner/Operator must evaluate the need for interim abatement measures when the contaminants are at levels that may be hazardous to human health and the environment. Abatement measures will commonly be needed to

Table 2-1: Applicable Point of Compliance (POC) and Point of Exposure (POE) Locations for Tier 2 SSCL Calculations

Exposure Pathway	Point of Compliance (source zone)	Point of Exposure Location	
		On-Site Receptor Type and POE	Off-Site Receptor Type and POE
Groundwater Exposure Pathways			
• GW Ingestion	Concentration in zone of affected GW plume > applicable Tier 1 criteria or > SSCLs.	• <i>Option 1:</i> Hypothetical well in plume area. Match receptor type to land use. • <i>Options 2-4:</i> For C/I property, no on-site POE unless existing water supply well located on site. For residential property, hypothetical residential well located in plume area.	• <i>Options 2-4:</i> Hypothetical residential well located at first downgradient off-site property (across downgradient ROW if ROW present at property line).
• Soil-to-GW Impact	Concentrations in affected soil zone > applicable Tier 1 criteria or > SSCLs.	• <i>Option 1:</i> Hypothetical well in plume area. Match receptor type to land use. • <i>Options 2-4:</i> For C/I property, no on-site POE unless existing water supply well located on site. For residential property, hypothetical residential well located in plume area.	• <i>Options 2-4:</i> Hypothetical residential well located at first downgradient off-site property (across downgradient ROW if ROW present at property line).
• GW Dermal Contact: Construction Worker in ROW	Concentrations in zone of affected GW plume > applicable Tier 1 criteria or > SSCLs.	• <i>All Options:</i> Construction worker in direct contact with affected GW within 0-15 ft below ground surface.	• <i>Options 2-4:</i> If hypothetical off-site well has been assumed to be located across ROW and depth to GW less than 15 ft, assume Const. Worker contacts affected GW at midpoint of ROW.
Soil Exposure Pathways			
• Soil Direct Contact: Ingestion, Dermal, Inhalation by Construction Worker	Concentrations in affected soil zone > applicable Tier 1 criteria or > SSCLs.	• <i>All Options:</i> Construction worker in direct contact with affected soils within 0-15 ft below ground surface.	• <i>All Options:</i> No off-site POE unless affected soil zone extends off-site.
Air Exposure Pathways			
• Soil to Ambient Air	Concentrations in affected soil zone > applicable Tier 1 criteria or > SSCLs. Affected soil zone.	• <i>All Options:</i> Site resident or site worker (depending on land use) at downwind edge of source zone.	• <i>Options 2-4:</i> Resident located at first off-site structure.
• GW to Ambient Air	Maximum concentration zone of affected GW plume.	• <i>All Options:</i> Site resident or site worker (depending on land use) at downwind edge of source zone.	• <i>Options 2-4:</i> Resident located at first off-site structure.
• Soil to Indoor Air	Affected soil zone beneath or immediately adjacent* to building.	• <i>All Options:</i> Site resident or site worker (depending on land use), in existing structure (if any) located atop source zone.	• <i>Options 2-4:</i> No off-site POE access affected soil zone extends off-site beneath existing structure.
• GW to Indoor Air	Affected GW plume beneath or immediately adjacent* to building.	• <i>All Options:</i> Site resident or site worker (depending on land use), in existing structure (if any) located atop source zone.	• <i>Options 2-4:</i> Resident in existing structure (if any) located atop off-site portion of GW plume.
<p>* “Immediately adjacent” to a building means the area within a one foot lateral perimeter of a structure.</p> <p>1) For each complete exposure pathway, hypothetical receptors and POE locations specified above must be assumed for purpose of Tier 2 Option 1-4 SSCL calculations. On-site land use should be classified based on current conditions. Off-site land use is assumed to be residential unless existing ordinance or other legal restriction mandates commercial/industrial use. Options 1,2,3 and 4 refer to Tier 2 SSCL calculation options, as described in this guide.</p> <p>2) C/I = Commercial/Industrial GW = Groundwater POC = Point of Compliance POE = Point of Exposure ROW = Right of Way (roadway, drainage structure, etc.)</p> <p>SSCL = Site-Specific Cleanup Level</p>			

control near-term impacts while the site evaluation effort proceeds. Abatement measures should be practical and reliable control actions which can be promptly implemented by the Owner/Operator. Examples of abatement measures may include placement of interim soil covers, installation of a vapor extraction system to control vapors, or installation of limited groundwater recovery wells to achieve hydraulic control of off-site plume migration.

Tier 2 Exposure Assumptions and Evaluation Procedures

Under Options 1 through 4, SSCLs for complete exposure pathways must be derived on the basis of the mandatory Tier 2 exposure assumptions specified in this document. For each exposure pathway, these mandatory exposure assumptions are designed to be protective of current and future land use conditions and consist of the following: (1) the type of receptor (resident, commercial/industrial site worker, or construction worker); (2) the point of exposure (i.e., the receptor location), and; (3) standard exposure factors defining the degree and duration of the exposure. Requirements applicable to cleanup level calculations under Tier 2 Options 1 through 4 are as follows:

- ***Type of Receptor:*** For each exposure pathway to be addressed in the Tier 2 Risk Assessment, the applicable receptor type for both on-site and off-site exposure locations is specified in Table 2-1. In general, the receptor types are designated as follows:
 - ***On-Site Exposure Locations:*** Match receptor type (either residential or commercial/industrial) to the current and anticipated future (e.g., projected for five to 10 years) land use. For groundwater dermal contact and soil direct contact pathways, assume the receptor is a construction worker in all cases.
 - ***Off-Site Exposure Locations:*** Assume residential land use and residential receptors for all off-site adjoining properties, unless zoning or other legally enforceable land use restrictions indicate commercial/industrial development and no one is living on the property. For the groundwater dermal contact pathway (if applicable), assume the receptor is a construction worker in all cases.
- ***Point of Exposure:*** The point of exposure (POE) represents the physical location where the pathway receptor is assumed to come into contact with an affected environmental medium (air, soil or groundwater). Table 2-1 specifies the POEs that are to be applied for complete exposure pathways under Tier 2 Options 1 through 4. Tier 2 Option 1 applies only to sites where no off-site soil or groundwater impacts are present or likely to occur. Consequently, under Option 1, SSCLs are equivalent to risk-based screening levels (RBSLs) because they are derived for on-site POEs only.

For Tier 2 Options 2 through 4, which address both on-site and off-site exposure conditions, the Owner/Operator must derive SSCLs for both on-site POEs and off-site POEs, as applicable. Under Options 2 through 4 for groundwater exposure pathways, hypothetical water supply wells must be assumed to be present at the first down-gradient off-site property (or across the down-gradient right-of-way if a right-of-way is present at the site property line). This POE location ensures that the calculated SSCLs will be protective of potential future off-site groundwater users.

- ***Exposure Factors:*** For each receptor type (resident, commercial/industrial site worker, or construction worker), standard exposure factors such as exposure duration, exposure frequency, intake rate and body weight are employed to calculate RBSLs and SSCLs. These exposure factors are specified on Worksheet #2 in Appendix A. For residential and commercial/industrial receptors, these values correspond to Reasonable Maximum Exposure (RME) scenarios established under EPA guidelines (U.S. Environmental Protection Agency, 1989). For each complete exposure pathway, the exposure factors from Worksheet #2 should be selected according to the receptor type specified for that pathway on Table 2-1.

Cleanup Criteria and Applicable Monitoring Locations

Tier 2 SSCLs represent COC concentration limits to be achieved at the source zone, or *point of compliance* (POC) such that TER limits will not be exceeded at an associated *point of exposure* (POE). For example, for the soil vapor-to-ambient air exposure pathway, reducing contaminant concentrations in the affected soil zone (i.e., the POC) to the applicable SSCL prevents exceedance of chronic risk levels for persons breathing ambient site air (i.e., POE).

POC and POE locations, as defined for the purpose of the Tier 2 Risk Assessment, are illustrated on Figure 2-2. Applicable POC and POE locations for each of the potential exposure pathways to be addressed in the Tier 2 Risk Assessment are summarized on Table 2-1. Further discussion of these measurement locations and the applicable Tier 2 cleanup criteria are provided below.

- ***On-Site Exposures:*** As shown in Table 2-1 for on-site POEs, exposure is assumed to occur in the immediate proximity of the soil or groundwater source area and the POE is effectively equal to the POC.

For contaminated soils, the source area corresponds to the full lateral and vertical extent of soils containing COCs in excess of Tier 1 criteria. For contaminated groundwater plumes, the source area corresponds to the zone of highest concentration above Tier 1 criteria, as detailed on Figure 2-3. For each COC, upper-bound soil and groundwater concentration limits, termed risk-based screening levels (RBSLs), are derived such that TER limits will not be exceeded at the relevant on-site POE. The RBSL represents a conservative contaminant concentration limit that is safe for human exposure at the source area such as direct ingestion of groundwater, or inhalation of dust or vapors from on-site soils.

RBSLs equations for each of the potential on-site exposure pathways to be addressed in the Tier 2 Risk Assessment are provided as Equations C.1 through C.8 in Appendix C, Table C-1. These expressions are to be used under Tier Options 1 and 2 to derive RBSL values protective of the applicable on-site POEs as specified on Table 2-1.

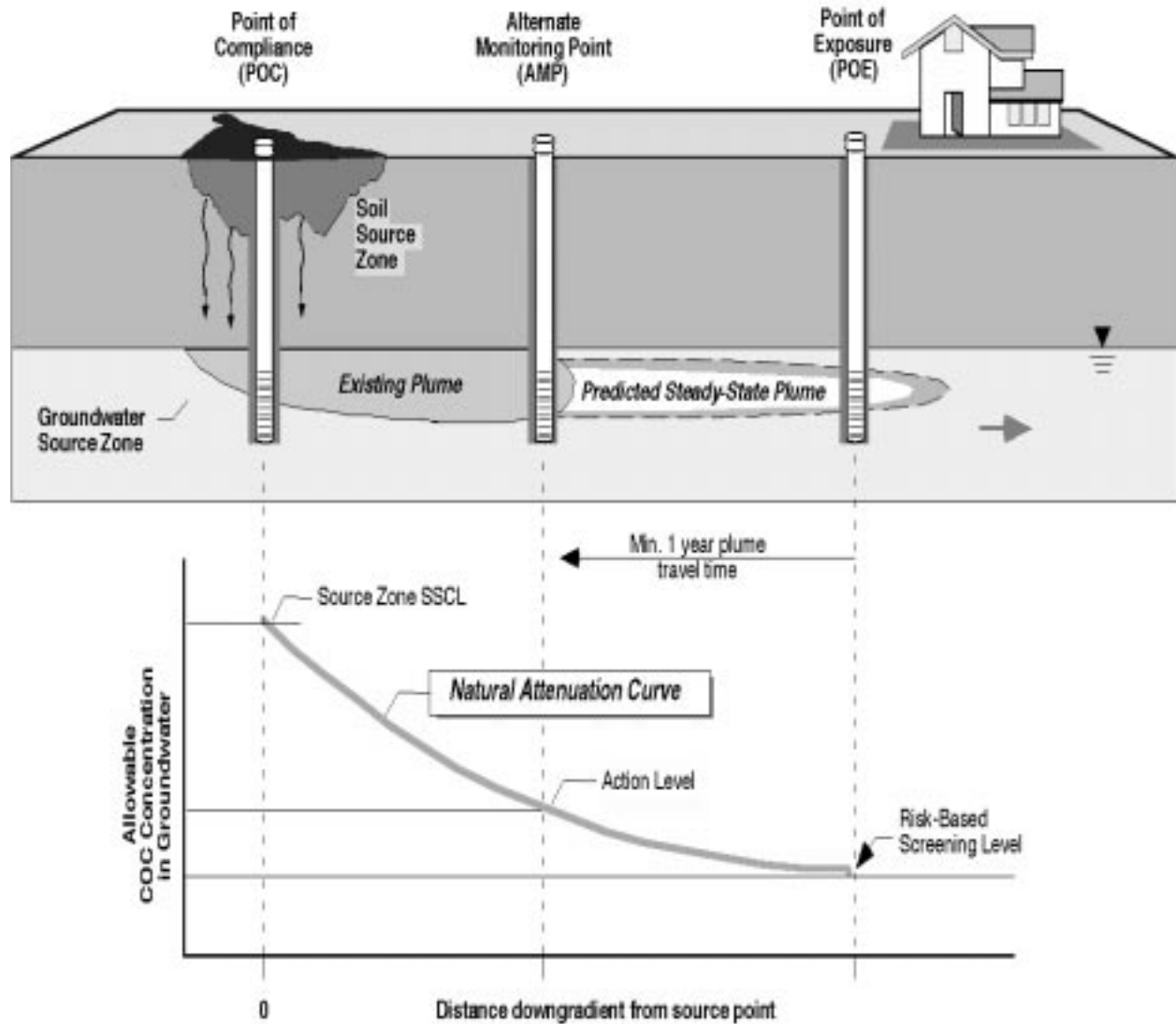
As discussed in further detail below, under Tier 2 Options 3 and 4, alternate methods may be employed to estimate the cross-media transfer factors incorporated in these RBSL equations, such as volatilization factor, particulate emission factor and leaching factor. These are addressed in Equations C.9 through C.21 in Appendix C, Table C-1. However, all other terms in the RBSL expressions that are provided in Equations C.1 through C.8, such as risk limits and exposure factors, are fixed for all Tier 2 Options. For groundwater exposure pathways, including groundwater ingestion and soil-to-groundwater leaching, in which a federal or state MCL value has been promulgated for a COC, the MCL must be used in place of the RBSL number that is derived from Equation C.2

For each complete exposure pathway and COC, RBSL values must be derived for the applicable on-site POEs. These values are compared to measured soil and groundwater source concentrations to determine the need for corrective action.

The applicability of an on-site POE depends on the exposure pathway and the on-site land use, as specified on Table 2-1. For example, if the on-site land use is commercial/ industrial:

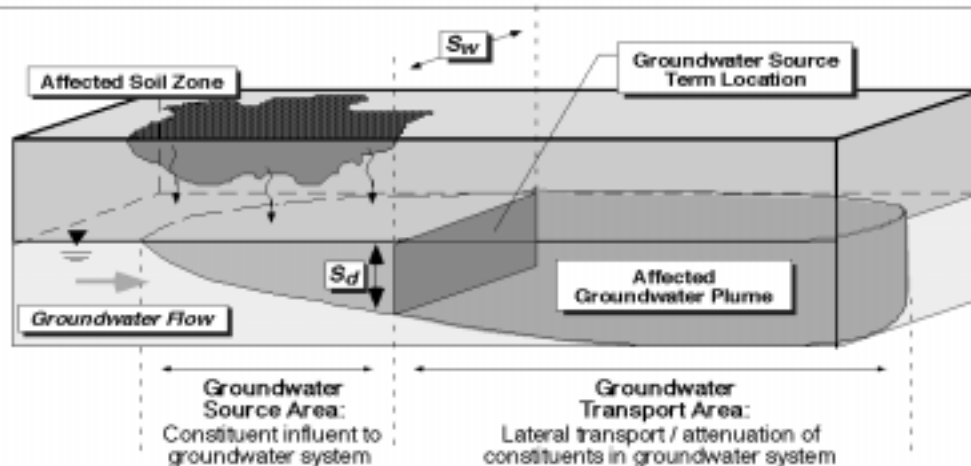
- No on-site POE is assumed for the groundwater for ambient air exposure pathways (soil-to-ambient air, groundwater-to-ambient air);
- On-site exposure is assumed to occur in all other exposure pathways, and;
- An RBSL must be derived for the designated receptor type and POE.

FIGURE 2-2: COMPLIANCE MONITORING LOCATIONS AND APPLICABLE CONCENTRATION LIMITS



Monitoring Location	Applicable Concentration Limit
POC	Site-Specific Cleanup Level (SSCL)
AMP	Action Level
POE	Risk-Based Screening Level (RBSL)

FIGURE 2-3: DEFINITION OF SOURCE TERM FOR USE IN DOMENICO SOLUTE TRANSPORT MODEL (EQUATIONS C-22 or C-23)



SELECTION OF GROUNDWATER MODEL INPUT PARAMETERS

For use of Domenico groundwater solute transport model (see Equations C-22 and C-23), select source term location, dimensions, and concentration as follows:

1) Groundwater Source Term Location

The source term corresponds to a vertical source plane, normal to the direction of groundwater flow, located at the downgradient limit of the area serving as the principal source of constituent release to groundwater (e.g., affected unsaturated zone soils, NAPL plume, spill area, etc.). If the point of maximum plume concentration is significantly displaced from the initial suspected point of release, this plume "hot spot" should be used as the source point for the groundwater ingestion pathway. However, the downgradient edge of the affected soil zone should be retained as the source location for the soil-to-groundwater leaching pathway. Distances to downgradient points of exposure (POEs) should then be measured from the applicable source location along the principal direction of groundwater flow.

2) Groundwater Source Term Width, S_w

The width of the source term should be matched to the **greater** of the following dimensions:

- i) the measured groundwater plume width, (as defined by Tier 1 criteria), perpendicular to the principal direction of groundwater flow at the designated source term location.
- ii) the maximum width of the affected soil zone (as defined by Tier 1 criteria), perpendicular to the principal groundwater flow direction.

3) Groundwater Source Term Thickness, S_d

The thickness of the source term should be determined by one of the following methods:

- i) measure the vertical extent of the affected groundwater plume at the designated source term location, based on depth-specific groundwater sampling and testing; or
- ii) for unconfined water-bearing unit, estimate mixing zone depth at the source location based on the observed magnitude of water table fluctuation.

4) Groundwater Source Term Concentration, C_s

To calculate baseline risk levels, the user must also provide a groundwater source concentration for each constituent of concern (COC). The vertical plane source acts as a constant source term, applying these input concentrations to all groundwater flowing through the source location. Under a Tier 2 evaluation, the source concentration of each COC may be defined as follows:

- i) use the maximum concentration of each COC detected at the source location; or
- ii) if multiple sampling locations are available to characterize plume concentrations across the source term width S_w use either 95% UCL or maximum source concentration (whichever is lowest) for each constituent across this plume transect based on time-consistent measurements. For this purpose, a minimum of 3 to 4 wells should be sampled across the plume transect. Non-detect values should not be used in calculation of the source concentration.

- **Off-Site Exposures:** For soil exposure pathways, applicable POEs are limited to the on-site soil source area, unless the contaminated soil zone extends off-site to another property. However, for air and groundwater exposure pathways, constituents can migrate downwind or down-gradient of the initial on-site source area to impact potential off-site POE locations. Therefore, for these exposure pathways, both on-site and off-site POEs must be addressed, as specified on Table 2-1.

For off-site POEs, exposure is assumed to occur at some distance from soil or groundwater source areas (i.e., the POE does *not* equal the POC). In these cases, a SSCL is derived for the on-site source area such that TER limits will not be exceeded at the off-site POE. The SSCL value differs from the RBSL value because a natural attenuation factor (NAF) is applied to the RBSL to account for the natural reduction in constituent concentrations that occurs in the distance between the source and the POE. The NAF equals the concentration in the exposure medium at the source divided by the concentration in the same exposure medium at the POE. To develop appropriate NAF values, see the forthcoming section entitled “General Procedures for Deriving Tier 2 NAF values.

For each complete exposure pathway and COC, the general equation for each individual constituent SSCL is:

$$SSCL = RBSL \times NAF$$

where: RBSL = Risk-Based Screening Level for the COC at POEs for the selected exposure pathway, and;
 NAF = Natural Attenuation Factor, characterizing COC concentration reduction from the source to the POE.
 SSCL = Site-Specific Cleanup Level for the COC at POCs for the selected exposure pathway.

When the POE is located at the POC (e.g., on-site exposures), no attenuation occurs between the POC and the POE. In this case, the NAF is 1.0 and the SSCL equals the RBSL. However, when exposure occurs at some distance from the source, the NAF is greater than 1.0 due to various dilution-attenuation processes occurring during lateral transport, and the SSCL is therefore greater than the RBSL. If measured COC concentrations in the soil or groundwater source area exceed SSCL values for a complete exposure pathway, corrective measures are addressed as needed to prevent TER exceedance at the off-site POE location.

- **Alternate Monitoring Points:** If COC concentrations in the source area exceed applicable SSCLs for complete exposure pathways, corrective measures must be addressed to prevent TER exceedance at the relevant POE locations. In addition, for sites where the contaminant plumes may be expanding, protection of down-gradient receptors must be demonstrated by sampling at Alternate Monitoring Points (AMPs). As shown in Figure 2-2, AMPs are locations between the POC (source) and the POE (receptor) along the potential pathway of constituent transport. Measurements at AMPs are essential for determining compliance with the TERs at the POE by providing information regarding the attenuation of contamination between the POC and the POE.

To protect down-gradient receptors at the POE, monitoring at an AMP must show that the rate of COC release from the source is less than or equal to a site-specific *action level* (AL). This concept is illustrated in the graph in the middle of Figure 2-2. The AL value is determined from the same transport model(s) and same site data used for the SSCL calculation. AL concentration limits will decrease with increasing distance from the source area to the specified AMP location. When AMP ALs are exceeded, the

Owner/Operator may be required to implement corrective action measures to ensure protection of down-gradient receptors. See Appendix C, Figure C-1 for procedures for determining AMP locations and ALs for the AMPs.

Target Excess Risk Limits

The target excess risk (TER) limits to be employed in development of Tier 2 RBSL and SSCL values for individual constituents correspond to a target excess cancer risk of 10^{-6} (i.e., a one in one million chance of getting cancer) and a hazard quotient of 1.0 for non-carcinogenic effects. However, for the groundwater ingestion pathway, if a federal or state MCL has been promulgated for the constituent of concern, it must be used as the RBSL value at the POE. Source zone SSCLs are designed to prevent exceedance of RBSL concentrations at applicable POEs, and thereby incorporate these same TER limits.

Land Use Assumptions and Applicable Exposure Factors

For each complete exposure pathway and each COC, the Tier 2 RBSL and SSCL values are intended to serve as conservative concentration limits that are protective of current and future land use activities. Usually future land use is assumed to be the same as current land use for five to 10 years. Therefore, in Worksheet #2 of Appendix A, the DERR has specified default exposure assumptions for both residential and commercial/industrial land use conditions. Off-site adjoining private property should be assumed to be subject to residential use, unless:

- Land use is commercial or industrial;
- Zoning or other legally enforceable land use restrictions indicate commercial/industrial development, and;
- No one is living on the property.

Standard exposure factors such as intake rate, body weight, exposure duration and exposure frequency used in the RBSL and SSCL calculations are specified on Worksheet #2. These values compare to the RME scenarios established under EPA guidelines (U.S. Environmental Protection Agency, 1989). For each complete exposure pathway, the exposure factors from Worksheet #2 should be selected according to the receptor type (i.e., resident, commercial/industrial site worker, or construction worker) specified for that pathway on Table 2-1.

Constituents of Concern

For releases from USTs, the COCs to be addressed in the Tier 2 Risk Assessment may include benzene, toluene, ethylbenzene, total xylenes and naphthalene (BTEXN); methyl-tert-butyl ether (MTBE), and; total petroleum hydrocarbons (TPH). Analysis of other COCs may be based on product type (see Appendices D and E-1), and other substances stored, if applicable, as determined by the Executive Secretary (UST).

Development of RBSL or SSCL Values

For BTEXN and MTBE, SSCL calculations must be based on the toxicological dose-response parameters (i.e., slope factor, reference dose and reference concentration) specified in the most recent EPA Integrated Risk Information System (IRIS, U.S. Environmental Protection Agency, 1998a and 1998b), or other resource approved by the DERR. Toxicity data are provided in Table C-2, Appendix C of this document. For TPH, site-specific, dose-response parameter values for non-carcinogenic effects are to be derived using the procedures established by the DERR, as specified below. In the Tier 2 Risk Assessment process, SSCL values for TPH in soil or groundwater must be derived for any relevant exposure pathways determined to be complete in the SCHEM. These include all of the exposure pathways listed in the first column of Table 2-1 (i.e., soil dermal/ingestion/inhalation; soil-to-air; or soil-to-groundwater and groundwater ingestion).

The DERR requires use of standard EPA analytical methods to determine concentrations of TPH fractions and other important COCs in petroleum products. The DERR's method of TPH fraction evaluation is derived and modified from the TPH Criteria Working Group (TPHCWG) method described in Edwards et al. (1997) and Gustafson et al. (1997). The DERR's method differs from the TPHCWG method mainly in the laboratory methods that are used to analyze TPH fractions. The TPHCWG method employs modified EPA Method 8015 to evaluate 13 TPH fractions. The DERR's method, however, employs EPA analytical methods 8260B and 8270B (EPA SW-846) to evaluate 10 TPH fractions. These latter EPA methods are less expensive to perform, and they are capable of achieving lower detection limits and creating more reproducible results and consistency between laboratories and sampling events.

The DERR's TPH fraction evaluation method uses the same fraction-specific reference doses (RfDs), reference concentrations (RfCs), and fate-and-transport parameters that are provided in the TPHCWG method (Edwards et al., 1997, and Gustafson et al., 1997). Appendix C, Table C-2 of this document summarizes these toxicity and fate and transport parameters. These parameter values can be used in the exposure equations provided in Table C-1 to calculate fraction-specific RBSL or SSCL values for complete exposure pathways. Measured concentrations of each TPH fraction are then compared to their calculated SSCL values to determine the need for corrective action. Appendix C, Table C-3 provides summary guidelines regarding sample collection and testing for TPH fractions.

In the Tier 2 Risk Assessment, TPH RBSL or SSCL values that are calculated using the DERR method will be required to achieve LUST case file closure for complete pathways with TPH-contaminated source media. The DERR evaluation method can be conducted during the Tier 2 Risk Assessment to facilitate development of relevant SSCL values for use in evaluation of the CAP. Alternatively, if the Owner/Operator anticipates corrective action for the complete pathway(s) due to the presence of other contaminants such as BTEXN or MTBE, the DERR method of analysis may be postponed until just prior to the Owner's/Operator's request for LUST case file closure, when it will be needed to demonstrate completion of the approved corrective action.

General Procedures for Deriving Tier 2 NAF Values

In the Tier 2 Risk Assessment, SSCL values for each complete exposure pathway and COC can be calculated by first solving the RBSL equations for the appropriate receptor type, and then by multiplying the RBSL by the lateral transport NAF to derive the corresponding SSCL. NAF values can be calculated by either of the two following methods:

- ***Empirical Analysis:*** Calculate a NAF based on the actual measured concentration ratio between the source medium and the POE and/or points in between, such as AMPs.
- ***Fate and Transport Modeling:*** Estimate a NAF based upon fate and transport modeling to predict concentration reductions between the source area and the POE.

Appropriate NAF values must be determined from a minimum of three, four and six sampling points located along the dissolved plume centerline for Option 2, Option 3 and Option 4, respectively. Analytical expressions for deriving NAF values for lateral contaminant transport in air and groundwater are provided by Equations C.22, C.23, C.24 and C.25 in Table C-1.

If the contaminant plume is shown to be stable or diminishing in size and concentration, empirical measurements can be employed to calculate the NAF value based on the ratio of COC concentrations in the exposure

medium (i.e., air or groundwater) at the source to the COC concentration in the same medium at the POE. Equation C.25 in Appendix C, Table C-1 is used for this calculation. If the contaminant plume cannot be shown to be stable or diminishing, a conservative estimate of the NAF must be derived using fate and transport modeling methods based on site-specific data.

- For groundwater exposure pathways, the NAF value is commonly referred to as a Dilution Attenuation Factor (DAF), which may be estimated using Equations C.22 or C.23 and site-specific input parameters.
- For air exposure pathways, natural attenuation of air contaminant concentrations downwind of a source area is characterized by a lateral Air Dispersion Factor (ADF), which is calculated using Equation C.24.

For any given pathway, an SSCL value protective of a specific off-site POE location can be derived by multiplying the RBSL for the applicable exposure pathway by the NAF value. For example, to derive an on-site groundwater SSCL that is protective of an off-site water well user to the TER or RBSL, multiply the RBSL for on-site groundwater (i.e., $RBSL_{wing}$; see Equation C.2) by the NAF value for lateral groundwater transport (i.e., groundwater DAF from Equations C.22 or C.23) between the on-site groundwater source area and the off-site POE location. The RBSL value must be calculated for the appropriate off-site receptor type (e.g., resident) in accordance with Table 2-1.

Equations C.22, C.23, C.24 and C.25 are intended to provide conservative (lower-bound) estimates of NAF values for air and groundwater transport based on use of appropriate, site-specific values. However, as discussed in further detail below, alternate modeling methods for estimation of site-specific NAFs can be employed under Tier 2 Options 3 or 4.

2.3 Tier 2 Options 1 through 4 Data Requirements and Calculation Methods

Site-specific data requirements for each option in Tier 2 are identified in Appendix A, Worksheet #2. The site-specific data include, at a minimum:

- Nature, type, extent and degree of contamination;
- Hydrogeologic data, and;
- Location of all receptors.

The site-specific data provide the essential input parameter values for deriving risk-based SSCLs, and aid in determining if exposure pathways are currently complete and whether there is a risk to receptors.

Utah's Tier 2 Risk Assessment process provides four options described below for solving the exposure equations and deriving SSCLs. Each successively higher option requires increasingly more accurate site-specific data, and increasingly sophisticated contaminant fate and transport modeling to achieve greater accuracy and certainty in evaluating risks to receptors. Upgrading to the next option is recommended if DERR and Owner/Operator determine the following:

- That cleanup to calculated SSCLs is not reasonable;
- There is reason to believe that the costs of collecting additional data and performing additional calculations may be offset by lower cleanup costs, and;
- That higher options may achieve greater accuracy in evaluating the nature and fate of contamination, and in deriving cleanup levels.

The four options of Tier 2 are described below:

- **Option 1 Site-Specific Cleanup Levels (Option 1 SSCLs):** Option 1 is the simplest form of the Tier 2 Risk Assessment and generally pertains to only soil or small groundwater plumes. Utah's Option 1 SSCLs are equivalent to "screening levels" in ASTM (1995) because, like Tier 1 SLs, they represent contaminant concentrations that are estimated to be protective of *on-site receptors* to the TER in situations without any off-site receptors.
 - Option 1 is for on-site receptors only, with no off-site contamination. Therefore, the SSCL equals the RBSL and NAFs are not applicable.
 - Contaminant plumes must be stable or decreasing in contaminant mass and plume size, and must not extend off-site. However, because Option 1 is the only option that does not require long-term monitoring, plume stability may not be possible to determine and option upgrade may be necessary.
 - Option 1 SSCLs are calculated for individual constituents using the minimum site-specific parameter data and the exposure equations identified in Appendices A, B and C.
- **Option 2 Site-Specific Cleanup Levels (Option 2 SSCLs)** are determined for the source area that are estimated to be protective of both *on-site and, if applicable, off-site* receptors. Option 2 SSCLs are equivalent to "site-specific target levels" (SSTLs) in ASTM (1995).
 - Because off-site receptors may be present in Option 2, NAFs for groundwater can therefore be applied (i.e., $SSCLs = RBSLs \times NAF$). Groundwater NAFs may be derived empirically based on field-measured concentrations and distance between measurement points.
 - Contaminant plumes must be stable or diminishing. At least one year of quarterly monitoring is required to determine plume stability.
 - Option 2 SSCLs are calculated for individual constituents using a relatively small amount of site-specific data and the exposure and cross-media transport equations (i.e., calculated RBSLs).

For the soil and air exposure pathways, Option 2 SSCLs are directly calculated using the equations in Appendix C, Table C-1. For groundwater exposure pathways, the user may first evaluate the plume stability condition using Worksheets #4a through #4e in Appendix A. For stable or diminishing groundwater plumes, an empirical NAF calculation should be obtained. For plumes that cannot be shown to be diminishing or stable, Option 2 does not apply. For such plumes, the Owner/Operator may elect to submit a CAP in accordance with Step 1.10 in Section 1 of this document. In this case, cleanup to applicable standards will be required. Alternatively, the Owner/Operator may proceed to the more detailed evaluations in Option 3.

- **Option 3 Site-Specific Cleanup Levels (Option 3 SSCLs)** are individual COC concentrations for the source area that are estimated to be protective of *on-site and, if applicable, off-site* receptors. Because off-site receptors may be present in Option 3, NAFs can be applied (i.e., $SSCLs = RBSLs \times NAF$).

Contaminant plumes may be stable, decreasing or increasing in plume size. At least two years of quarterly monitoring are required to determine plume stability.

Option 3 SSCLs and ALs for AMPs are derived by first solving the exposure and cross-media transport equations provided in Appendix C, Table C-1. For any exposure pathway or COC for which the initial SSCLs or ALs are exceeded, transient models are employed to improve the certainty of the SSCL and AL calculations. The transient modeling produces a two-fold result:

- The allowable SSCL for exposure pathways and COCs, and;
 - The duration and fate of the COCs if their applicable preliminary SSCLs are exceeded.
- **Option 4 Site-Specific Cleanup Levels (Option 4 SSCLs)** are equivalent to ASTM (1995) Tier 3 SSTLs and are determined when Options 2 and 3 SSCLs cannot be reasonably achieved. Owners/Operators must demonstrate significant cost savings before proceeding with an Option 4 Risk Assessment.

Option 4 SSCLs are COC concentrations determined for individual constituents for the source area that are protective of *on-site and, if applicable, off-site* receptors. Because off-site receptors may be present in Option 4, NAFs can be applied (i.e., SSCLs = RBSLs X NAF).

Like Option 3, Option 4 may be performed for contaminant plumes that are stable, decreasing or increasing in plume size. At least five years of monitoring are required to determine plume stability.

Option 4 requires rigorous subsurface investigation, contaminant characterization, and sophisticated analytical and numerical chemical fate and transport modeling for each medium of concern. Option 4 initial SSCLs for the source area and ALs for AMPs are derived by first solving the exposure and cross-media transport equations provided in Appendix C, Table C-1. For any exposure pathway or COC for which the initial SSCLs or ALs are exceeded, transient models are employed to improve the certainty of the SSCL and AL calculations. The transient modeling produces a two-fold result:

- The allowable SSCL for exposure pathways and COC, and;
- The duration and fate of the COCs if their applicable preliminary SSCLs are exceeded.

2.4 Tier 2 Step-By-Step Procedures and Documentation

The following step-wise Utah Tier 2 Risk Assessment process corresponds to the numbered Steps 2.1 through 2.27 on Figure 2-1 “Flow Chart of Utah’s RBCA Tier 2 Risk Assessment Process.” Each step provides instructions to Owners/Operators for conducting the site-specific risk assessment. The instructions identify data requirements and reporting formats for each step. The completed Tier 2 Risk Assessment report for any option to be submitted to the DERR must contain the following elements:

- Appendix A: Completed Tier 2 Worksheets #1, #2, #3, and #4a through #4e, if applicable.
- Appendix B: Site-specific raw data, including maps, cross-sections, graphs, boring test pit logs, monitoring well construction diagrams, pump or slug test data and results, and analytical data.
- Appendix C: Calculations, parameter input values and solutions to the equations that are used to derive Tier 2 SSCLs and ALs for AMPs. Modeling input, output and graphics.

The DERR encourages all Owners/Operators to contact their UST certified consultant and the DERR project manager with questions regarding the DERR’s Tier 2 Risk Assessment process.

Step 2.1: Are Applicable Tier 1 Groundwater Screening Levels Exceeded?

The Owner/Operator is responsible for determining if the Tier 1 SLs for groundwater are exceeded based on the data collected.

Yes: GO TO STEP 2.8 if the Tier 1 SLs for groundwater are exceeded. The Owner/Operator conducts a Tier 2 Option 2 risk assessment.

No: GO TO STEP 2.2 if the Tier 1 SLs for groundwater are not exceeded. The Owner/Operator conducts Tier 2 Option 1 risk assessment.

Step 2.2: OPTION 1: Are the Site-Specific Data Sufficient to Calculate Option 1 Cleanup Levels?

The Owner/Operator needs site-specific data to calculate Option 1 SSCLs and to ensure a sufficient degree of certainty in assessing the risk to receptors. Because site-specific data are generally not available from UST closure results, the Owner/Operator often needs to collect the site-specific data by conducting additional subsurface investigations. The site-specific data required for Option 1 are identified in Worksheet #2 of Appendix A, and Appendices B and C.

Option 1 is the simplest form of the Tier 2 Risk Assessment. It is beneficial because it requires only a small amount of site-specific data, usually gathered during the initial Subsurface Investigation, and does not require long-term monitoring or transient contaminant fate and transport modeling. Option 1, however, requires that contaminant plumes be stable or diminishing. It may not be possible to confirm this condition without monitoring data or an upgrade to a higher option.

Option 1 SSCLs represent on-site concentrations of individual contaminant constituents at the source area in soil and groundwater that are expected to be protective of on-site receptors to applicable MCLs, the TER, or other applicable standards, for all exposure media and pathways. Because the receptor is assumed to be at the source area in Option 1, there is no NAF. Therefore, the Option 1 SSCL is equal to the RBSL. ***If the contamination is off-site or if there are off-site receptors, go to Step 2.8 and upgrade to Option 2.***

The differences between Tier 1 (Utah Department of Environmental Quality, DERR, 1997) SLs and Tier 2 Option 1 SSCLs include the following:

- Tier 1 SLs are for screening purposes only, consider only selected exposure pathways, and are based on limited, general and conservative assumptions characteristic of Utah's intermontane basins.
- A Tier 2 Option 1 risk assessment allows the use of site-specific data collected from subsurface investigations to evaluate the risks to on-site receptors for all three exposure pathways (air, groundwater and soil).
- Tier 1 groundwater SLs are based on ingestion of the groundwater which must meet the MCL standards (approximately 10^{-6} TER). In contrast, Tier 2 allows for the evaluation of all exposure pathways, such as the vapor-intrusion-to-indoor air inhalation pathway. Therefore, depending on the site-specific conditions, Tier 2 Option 1 soil SSCLs may be higher or lower than the Tier 1 SLs.

Yes: GO TO STEP 2.4 to calculate Option 1 SSCLs and determine if SSCLs are exceeded.

No: GO TO STEP 2.3 and conduct additional subsurface investigations to gather the necessary site-specific data for calculating Option 1 SSCLs.

Step 2.3: Owner/Operator Conducts Additional Investigations

If site-specific data are not sufficient for calculating Option 1 SSCLs, the Owner/Operator must conduct additional investigations. These may include collecting samples to characterize and define the extent and degree of contamination, characterize hydrogeologic conditions, locate all on-site receptors, and identify and evaluate all exposure media and exposure pathways. Additional investigation usually involves collecting representative environmental samples and gathering other data required by Worksheet #2 through such activities as digging, drilling or direct-push methods, laboratory analysis and aquifer testing.

GO TO STEP 2.2 to ensure there are sufficient site-specific data to calculate Option 1 SSCLs.

**Step 2.4: **OPTION 1: Owner/Operator Calculates Option 1 Site-Specific Cleanup Levels:
Are the Option 1 SSCLs Exceeded?****

After meeting the Option 1 data requirements (see Section 3, Worksheet #2 in Appendix A , and Appendices B and C of this document), Option 1 SSCLs are calculated by solving the equations in Table C-1 of Appendix C for individual constituents and for all complete exposure pathways. Commercially available electronic spreadsheets may also be used to calculate SSCLs. Option 1 SSCLs are equal to the RBSLs because receptors are assumed to be located at the source area and there is therefore no NAF.

The Owner/Operator then determines if the contaminant concentrations exceed the calculated SSCLs by comparing the maximum observed contaminant concentrations to the calculated Option 1 SSCLs for all complete exposure pathways. ***The final Option 1 SSCLs are the lowest concentrations that are calculated for any of the complete exposure pathways.***

Detailed procedures and reporting formats for calculating Option 1 SSCLs and presenting the Option 1 Risk Assessment are shown in Section 3 and Appendices A, B and C of this document.

Yes: GO TO STEP 2.5 if the contaminant concentrations are greater than the lowest concentrations calculated for any complete exposure pathway.

No: GO TO STEP 2.23 if the contaminant concentrations are less than the lowest concentrations calculated for any complete exposure pathway.

Step 2.5: *Is Cleanup to Option 1 SSCLs Reasonable?*

The Owner/Operator determines if cleanup measures are reasonable by comparing the costs of collecting additional site-specific data to support higher levels of the risk assessment using Options 2 through 4 with the costs of performing cleanup to achieve lower-tier cleanup levels (e.g. Option 1 or Tier 1 criteria). Owners/Operators can use the information contained in their original RAP to compare the costs of performing further risk assessment to conducting cleanup. ***The Owners/Operator may find that conducting additional subsurface investigations to perform higher option requirements are more costly than cleaning up the contamination.***

An example of a cleanup that ***may*** be considered reasonable because it is economically and technologically feasible where receptors are not immediately at risk may include the following:

- Contaminated soil occurs at a shallow depth and can be removed for a reasonable cost.

An example of conditions that may render cleanup ***not*** reasonable because it is not economically and technologically feasible may include the following:

- Contaminated soil is located from 35 to 40 feet below land surface and groundwater is not expected to be impacted. The soil cannot be removed for a reasonable cost and receptors are expected to be protected.

If any remaining contamination has the potential to threaten receptors or impact future land use, cleanup and/or environmental controls may be necessary. See Step 2.25 for examples of environmental controls.

Yes: GO TO STEP 2.22 if cleanup to Option 1 SSCLs *is* reasonable. The Owner/Operator then submits a CAP in accordance with Figure 1-1, Step 1.10. The Owner/Operator identifies cleanup options and proposes the most reasonable method to clean up the contamination to applicable cleanup standards.

No: GO TO STEP 2.6 if cleanup to Option 1 SSCLs *is not* reasonable. The Owner/Operator determines if response action is necessary based on all of the data collected.

Step 2.6: Is Response Action Necessary?

Response action may be necessary for protecting receptors due to changing site conditions or land use which indicate that receptors are at risk. This may include either current receptors, or receptors that could be affected following changes in land use. The Executive Secretary (UST) may require response action if contaminant sources are not eliminated by removal or control (e.g., if secondary sources remain, or have the potential to further degrade natural resources or to threaten receptors). See Step 2.7 for examples of response actions.

Yes: GO TO STEP 2.7: The Owner/Operator takes necessary response actions according to the Site Classification requirements shown in Tier 1 (Utah Department of Environmental Quality, DERR, 1997).

No: GO TO STEP 2.8 to implement Option 2.

Step 2.7: Take Interim Response Action

Owners/Operators must take appropriate response actions. Response actions may include providing partial or continued source removal, implementing contaminated soil or groundwater removal, providing alternative water supply, evacuating vapors from structures, or other actions necessary to reduce risks to receptors.

GO TO Tier 1 Site Classification (Utah Department of Environmental Quality, DERR, 1997). After response actions have been satisfactorily completed, the Owner/Operator may proceed with any applicable cleanup or begin the Tier 2 Risk Assessment process again.

Step 2.8: OPTION 2: Are the Site-Specific Data Sufficient to Calculate Option 2 Cleanup Levels?

The Owner/Operator needs site-specific data to calculate Option 2 SSCLs for the source area and to ensure a sufficient degree of certainty in assessing the risk to receptors. Site-specific data requirements are greater for Option 2 than for Option 1, and the Owner/Operator needs to collect the required data by conducting additional subsurface investigations. The additional investigations are used to help further define the extent and degree of contamination in soil and groundwater, identify on-site and off-site receptors, and better define the nature and migration potential of the contamination relative to receptors, exposure pathways and exposure media.

The site-specific data required for Option 2 are identified in Worksheet #2 of Appendix A, and Appendices B and C.

Option 2 is more complex than Option 1 because it requires more data points and one year of quarterly monitoring. The monitoring must include analysis of BTEXN/MTBE/TPH, or other constituents based on product type, and the analysis of natural attenuation parameters to ensure the contaminant plume is stable or diminishing.

Option 2 provides for the evaluation of *off-site* as well as *on-site* receptors. Like Option 1, Option 2 does not require transient modeling. The additional data and complexity of Option 2 can be beneficial because the data add a greater degree of certainty in assessing risk to receptors.

Option 2 SSCLs represent concentrations of individual contaminant constituents in soil and groundwater that are expected to be protective of on-site and off-site receptors to applicable MCLs, the TER or other applicable standards for all exposure media and pathways.

- Yes:** GO TO STEP 2.10 to calculate Option 2 SSCLs and to determine if the calculated Option 2 SSCLs are exceeded.
- No:** GO TO STEP 2.9 and conduct additional subsurface investigation to gather the necessary site-specific data.

Step 2.9: Owner/Operator Conducts Additional Investigation

If site-specific data are not sufficient for calculating Option 2 SSCLs, the Owner/Operator must conduct additional investigations. These may include collecting samples to characterize and define the extent and degree of contamination, characterize hydrogeologic conditions, locate all on-site receptors, and identify and evaluate all exposure media and exposure pathways. Additional investigation usually involves collecting representative environmental samples and gathering other data required by Worksheet #2 through such activities as digging, drilling or direct-push methods, laboratory analysis and aquifer testing.

GO TO STEP 2.8 to ensure that the site-specific data are sufficient for calculating Option 2 SSCLs.

***Step 2.10: OPTION 2: Owner/Operator Calculates Option 2 Cleanup Levels for Soil and Groundwater:
Are the Option 2 SSCLs exceeded?***

After meeting the Option 2 data requirements (see Section 3, Worksheet #2 in Appendix A, and Appendices B and C of this document), Option 2 SSCLs are calculated by solving the equations in Table C-1 of Appendix C for individual constituents of concern for all complete exposure pathways. Commercially available electronic spreadsheets may be used to calculate SSCLs.

Option 2 may include evaluation of off-site receptors, or receptors that are located some distance from the source area. In those cases, a NAF can be calculated to derive final Option 2 SSCLs. NAFs can be calculated using Equations C.22, C.23, C.24 and C.25.

The Owner/Operator then determines if the contaminant concentrations exceed the calculated SSCLs by comparing the maximum observed contaminant concentrations of individual constituents to the calculated Option 2 SSCLs for all complete exposure pathways. ***The final Option 2 SSCLs are the lowest concentrations that are calculated for any of the complete exposure pathways.***

Detailed procedures and reporting formats for calculating Option 2 SSCLs and presenting the Option 2 Risk Assessment are shown in Section 3 of this document.

- Yes:** GO TO STEP 2.11 if the contaminant concentrations are greater than the lowest concentrations calculated for any complete exposure pathway.
- No:** GO TO STEP 2.23 if the contaminant concentrations are less than the lowest concentrations calculated for any complete exposure pathway.

Step 2.11: Is Cleanup to Option 2 SSCLs Reasonable?

The Owner/Operator determines if the cleanup measures are reasonable by comparing the costs of collecting additional site-specific data to support higher levels of the Tier 2 Risk Assessment using Options 3 or 4 with the costs of performing cleanup to achieve lower-option cleanup levels (e.g. Option 1 or Tier 1 criteria). Owners/Operators can use the information contained in their original RAP to compare the costs of performing further risk assessment to conducting cleanup. ***Owners/Operators may find that conducting rigorous additional subsurface investigations and performing contaminant fate and transport modeling are more costly than cleaning up the contamination.***

An example of cleanup under Option 2 that *may* be considered reasonable when receptors are not immediately at risk is the following:

- Contaminated soil has not been removed and groundwater monitoring wells installed. Groundwater sampling and hydraulic gradient monitoring indicate that contaminant concentrations are decreasing. Because the remaining soil contamination is above the calculated SSCLs, protective measures may need to be implemented. These protective measures are determined to be less costly than proceeding to Option 3.

An example of conditions that may render cleanup to Option 2 SSCLs unreasonable may include:

- A known area of soil contamination is located beneath a building and cannot be removed. Site-specific data indicate that the contamination occurs in clayey sediment beneath the building. Excavation is not reasonable because of the depth and location of the contamination beneath the building, and *in situ* soil treatment is not reasonable due to the low permeability of the fine-grained sediment. Further risk assessment is determined to be a reasonable method of ensuring protection of receptors to applicable levels.

Yes: GO TO STEP 2.22 if cleanup to Option 2 SSCLs *is* reasonable. The Owner/Operator submits a CAP in accordance with Figure 1-1, Step 1.10. the Owner/Operator identifies cleanup options and proposes the most reasonable method to clean up the contamination to applicable cleanup standards.

No: GO TO STEP 2.12 if cleanup to Option 2 SSCLs *is not* reasonable. The Owner/Operator determines if response action is necessary based on all of the data collected.

Step 2.12: *Is Response Action Necessary?*

Response action may be necessary for protecting receptors due to changing site conditions or land use which indicate that receptors are at risk. This may include either current on-site and off-site receptors, or receptors that could be affected following changes in land use. The Executive Secretary (UST) may require response action if contaminant sources are not eliminated by removal or control (e.g., if secondary sources remain, or have the potential to further degrade natural resources or to threaten receptors). See Step 2.7 for examples of response actions.

Yes: GO TO STEP 2.7 where the Owner/Operator takes necessary response actions according to the Site Classification requirements shown in Tier 1 (Utah Department of Environmental Quality, DERR, 1997).

No: GO TO STEP 2.13 to implement Option 3.

Step 2.13: *OPTION 3: Are the Site-Specific Data Sufficient to Derive Option 3 SSCLs?*

The Owner/Operator needs sufficient site-specific data to calculate Option 3 SSCLs for the source area, and ALs for AMPs, to ensure a high degree of certainty in assessing the risk to receptors. Site-specific data requirements are greater for Option 3 than those for Options 1 and 2, and the Owner/Operator needs to collect the required data by conducting additional subsurface investigations. The additional subsurface investigations helps further define the extent and degree of contamination in soil and groundwater, identify on-site and off-site receptors, and collect increasingly more precise data needed for modeling the nature and migration potential of the contamination relative to receptors, exposure pathways and exposure media.

The site-specific data required for Option 3 are identified in Worksheet #2 of Appendix A, and Appendices B and C.

Option 3 is more complex than Option 2 because it requires more data points, two years of quarterly monitoring, and transient contaminant fate and transport modeling. The monitoring must include analysis of BTEXN/MTBE/TPH, or other constituents based on product type, and the analysis of natural attenuation parameters. The complexity and increased data requirements of Option 3 can be beneficial because of the greater degree of certainty in assessing risk to receptors.

Unlike Option 2, Option 3 contaminant plumes may be expanding. Transient modeling is therefore required to better understand the nature of the contamination and risk to receptors in space and time. *Like* Option 2, Option 3 requires that *off-site and on-site* receptors be evaluated.

Like the Option 2 SSCLs, Utah's Option 3 SSCLs represent concentrations of individual contaminant constituents in soil and groundwater that are expected to be protective of current and future exposure pathways and of on-site and off-site receptors to applicable MCLs, the TER or other applicable standards for all complete exposure pathways. The additional data and complexity of Option 3 can be beneficial because the greater degree of certainty in assessing risk to receptors may result in higher SSCLs and less costly cleanup.

Yes: GO TO STEP 2.15 to calculate Option 3 SSCLs and ALs and to determine if the calculated Option 3 SSCLs and ALs are exceeded.

No: GO TO STEP 2.14 and conduct additional investigation to gather the necessary site-specific data.

Step 2.14: Owner/Operator Conducts Additional Investigation and/or Monitoring

If site-specific data are not sufficient for deriving Option 3 SSCLs, the Owner/Operator must conduct additional investigations and/or monitoring. Additional investigations may include collecting samples to characterize and define the extent and degree of contamination, characterize hydrogeologic conditions, locate all on-site and off-site receptors, and identify and evaluate all complete exposure pathways. Additional investigation usually involves collecting representative environmental samples and gathering other data required by Worksheet #2 through such activities as digging, drilling or direct-push methods, laboratory analysis and aquifer testing. Two years of quarterly monitoring are required for Option 3 to estimate plume stability and contaminant mass balance, and to facilitate the use of transient analytical contaminant fate and transport models and derive Option 3 SSCLs and ALs for AMPs.

GO TO STEP 2.13 to ensure there are sufficient site-specific data to calculate Option 3 SSCLs Action Levels.

Step 2.15: OPTION 3: Owner/Operator Derives Option 3 Soil and Groundwater SSCLs and ALs for Individual Constituents:

Are the Option 3 SSCLs or ALs Exceeded?

After meeting the Option 3 data requirements (see Section 3, Worksheet #2 of Appendix A, and Appendices B and C of this document, Option 3 SSCLs and ALs for AMPs are calculated for individual constituents by solving the equations shown in Table C-1 and Figure C-1 of Appendix C. Placement of AMPs and calculation of associated ALs are required if the contaminant plume is not stable or is expanding. The Owner/Operator first calculates preliminary Option 3 SSCLs for all complete exposure pathways. Commercially available electronic spreadsheets may be used to solve the exposure and transport equations and calculate preliminary SSCLs. Transient analytical modeling is then performed to evaluate the effects and location of the contamination and the calculated SSCLs in space and time (i.e. transient conditions) to derive the final SSCLs.

The Owner/Operator compares the maximum observed contaminant concentrations of individual constituents to the calculated preliminary Option 3 SSCLs for all complete exposure pathways. If the calculated preliminary SSCLs are exceeded, the Owner/Operator may perform transient analytical contaminant fate and transport modeling to derive final SSCLs.

The final SSCLs and ALs are the contaminant concentrations that will be protective of receptors to the TER in space and time. ***The final Option 3 SSCLs and ALs are the lowest concentrations that are derived for any of the complete exposure pathways.***

Detailed procedures and reporting formats for calculating and deriving Option 3 SSCLs and ALs, and for presenting the Option 3 Risk Assessment are shown in Section 3 and Appendix C of this document.

Yes: GO TO STEP 2.16 if the contaminant concentrations in the source area exceed the derived Option 3 SSCLs and ALs, and if the contaminant concentrations are greater than the lowest concentrations calculated for a complete exposure pathway.

No: GO TO STEP 2.23 if the contaminant concentrations in the source area do not exceed the derived Option 3 SSCLs and ALs.

Step 2.16: Is Cleanup to Option 3 SSCLs Reasonable?

The Owner/Operator determines if the cleanup measures are reasonable by comparing the costs of collecting additional site-specific data to support an Option 4 Risk Assessment with the costs of performing cleanup to achieve lower-option cleanup levels (i.e., Option 1 or 2, or Tier 1 criteria). Owners/Operators can use the information contained in their original RAP to compare the costs of performing further risk assessment to conducting cleanup. ***The Owner/Operator may find that conducting additional subsurface investigations and collecting additional data necessary for performing Option 4 contaminant fate and transport modeling are more costly than cleaning up the contamination.***

An example of conditions under Option 3 where cleanup *may* be considered reasonable is the following:

- A large dissolved contaminant plume cannot be captured, contained or treated for a reasonable cost. Contaminated soil occurs at a shallow depth and appears to be leaching to groundwater and causing a dissolved contaminant plume. Quarterly monitoring of contaminant concentrations, depth to groundwater, hydraulic gradient, and dissolved oxygen and other natural attenuation parameters are used in transient analytical modeling. The monitoring and modeling results indicate that the plume is not migrating, but will continue to persist for many years. The modeling also indicates that if contaminated soil in the source area is removed, the contaminant mass currently leaching to the groundwater will be significantly reduced and the dissolved plume would be sufficiently degraded in three years. In addition, the property is being sold for development and any proposed buildings would be at risk of vapor intrusion. The most reasonable method of controlling the contaminant plume, expediting case file closure, and ensuring protection of receptors is removal of the contaminated soils.

An example of conditions under which cleanup to Option 3 SSCLs and ALs *may not* be considered reasonable is the following:

- A large dissolved contaminant plume occurs in a non-potable aquifer. The plume cannot be captured, contained or treated for a reasonable cost. Monitoring is no longer feasible due to changes in land use. Receptors are not currently or potentially at risk as a result of the land use change and as determined by transient analytical modeling. Long-term quarterly monitoring of the contaminant concentrations, depth to groundwater, hydraulic gradient, and dissolved oxygen indicates that the plume is stable and is decreasing in size and contaminant mass relatively quickly. Transient analytical modeling of individual constituents accurately reflects the quarterly monitoring data, and predicts that the plume will be sufficiently degraded within a short time. Further risk assessment using numerical modeling according to Option 4 is therefore determined to be the most cost-effective and feasible technology for ensuring protection of receptors to the applicable standards.

Yes: GO TO STEP 2.22 if the Owner/Operator determines that cleanup is reasonable.

No: GO TO STEP 2.17 if the Owner/Operator determines that cleanup is not reasonable.

Step 2.17: *Is Response Action Necessary?*

Response action may be necessary for protecting receptors due to changing site conditions or land use which indicate that receptors are at risk. This may include either current receptors, or receptors that could be affected following changes in land use. The Executive Secretary (UST) may require response action if contaminant sources are not eliminated by removal or control (e.g., if secondary sources remain, or have the potential to further degrade natural resources or to threaten receptors). See Step 2.7 for examples of response actions.

Yes: GO TO STEP 2.7 where the Owner/Operator takes necessary response actions according to the Site Classification requirements shown in Tier 1 (Utah Department of Environmental Quality, DERR, 1997).

No: GO TO STEP 2.18 to implement Option 4.

Step 2.18: *OPTION 4: Are the Site-Specific Data Sufficient to Derive Option 4 SSCLs?*

Option 4 is the most complex form of the Tier 2 Risk Assessment, but it provides the greatest accuracy in deriving SSCLs for the source area, establishing ALs for AMPs, and determining risk to receptors. Option 4 may be performed when the contaminant plume is diminishing, stable or expanding. Option 4 evaluations should be performed only when an Owner/Operator can demonstrate that performing an Option 4 risk assessment will result in significant cost savings compared to site cleanup for equal levels of protection.

Like Options 2 and 3, Option 4 requires the evaluation of on-site and off-site receptors for all exposure pathways and media. Option 4 is the most difficult because it requires more data points and site-specific data, a minimum of five years of quarterly monitoring for the COCs and for natural attenuation parameters, and transient analytical and transient numerical contaminant fate and transport modeling. The rigorous modeling is required to accurately evaluate the site conditions and the ability of the calculated SSCLs to be protective of current and future exposure pathways for both on-site and off-site receptors. Site-specific data requirements for Option 4 are shown in Worksheet #2 of Appendix A.

Additional investigation may be necessary to gather the necessary site-specific data. The additional subsurface investigations help further define the extent and degree of contamination in soil and groundwater, identify on-site and off-site receptors, and provide the precise data needed to support modeling of the nature and migration potential of the contamination relative to receptors, exposure pathways and exposure media. The large volume of data required for Option 4 is required to ensure a high degree of accuracy in characterizing the contamination, and ability to offer greater confidence in estimating risks to receptors.

Option 4 SSCLs represent concentrations of individual contaminant constituents in soil and groundwater that are expected to be protective of on-site and off-site receptors to applicable MCLs, the TER or other applicable standards for all exposure media and pathways.

Yes: GO TO STEP 2.20 to calculate Option 4 SSCLs and ALs and to determine if the calculated Option 4 SSCLs and ALs are exceeded.

No: GO TO STEP 2.19 and conduct additional investigations to gather more precise site-specific data.

Step 2.19: *Owner/Operator Conducts Additional Investigation*

If site-specific data are not sufficient for deriving Option 4 SSCLs, the Owner/Operator must conduct additional investigations and/or monitoring. Additional investigations may include collecting samples to characterize and define the extent and degree of contamination, characterize hydrogeologic conditions, locate all on-site and off-site receptors, and identify and evaluate all complete exposure pathways. Additional investigations usually involve collecting representative environmental samples, laboratory analysis or aquifer tests through activities such as excavating, drilling or direct-push methods. Five years of quarterly monitoring are required for Option 4 to estimate plume stability and contaminant mass balance, and to facilitate the use of transient analytical contaminant fate and transport models and derive Option 4 SSCLs and ALs for AMPs.

GO TO STEP 2.18 to determine if the site-specific data are sufficient to perform a Tier 2 Option 4 Risk Assessment.

Step 2.20: *OPTION 4: Owner/Operator Derives Option 4 Soil and Groundwater SSCLs and ALs for Individual Constituents:*
Are the Option 4 SSCLs or ALs Exceeded?

After meeting the Option 4 requirements (see Section 3, Worksheet #2 of Appendix A, and Appendices B and C), Option 4 SSCLs for the source area, and ALs for AMPs are calculated by solving the equations in Table C-1 and in Figure C-1 of Appendix C, respectively. Placement of AMPs and calculation of associated ALs are required for Option 4 if the contaminant plume is not stable or if it is expanding.

The Owner/Operator first calculates preliminary Option 4 SSCLs for all complete exposure pathways. Commercially available electronic spreadsheets may be used to solve the exposure and transport equations and calculate preliminary SSCLs. Transient analytical and numerical modeling are then performed to evaluate the effects and location of the contamination and the calculated SSCLs in space and time (i.e. transient conditions) to derive the final SSCLs.

The Owner/Operator then determines if the contaminant concentrations exceed the calculated preliminary SSCLs. To determine if the preliminary SSCLs are exceeded, the Owner/Operator compares the maximum observed contaminant concentrations of individual constituents to the calculated preliminary Option 4 SSCLs for all complete exposure pathways. If the calculated preliminary SSCLs are exceeded, or if the contaminant plume is increasing in size, or if the contamination is observed to be partitioned in various phases (e.g., adsorbed, dissolved, vapor) in space and time, the Owner/Operator may perform transient analytical and transient numerical contaminant fate and transport modeling to derive final SSCLs.

The final Option 4 SSCLs and ALs are the lowest concentrations that are derived for any of the complete exposure pathways. The final SSCLs and ALs are the contaminant concentrations that will be protective of receptors to the TER in space and time.

Detailed procedures and reporting formats for deriving Option 4 SSCLs and ALs, and for presenting the Option 4 Risk Assessment are shown in Section 3 of this document.

- Yes:** GO TO STEP 2.21 if the contaminant concentrations in the source area exceed the derived Option 4 SSCLs and ALs and if the contaminant concentrations are greater than the lowest concentrations calculated for a complete exposure pathway.
- No:** GO TO STEP 2.23 if the contaminant concentrations in the source area do not exceed the derived Option 4 SSCLs and ALs.

Step 2.21: Is Response Action Necessary?

Response action may be necessary for protecting receptors due to changing site conditions or land use which indicate that receptors are at risk. This may include either current on-site or off-site receptors, or receptors that could be affected following changes in land use. The Executive Secretary (UST) may require response action if contaminant sources are not eliminated by removal or control (e.g., if secondary sources remain, or have the potential to further degrade natural resources or to threaten receptors). See Step 2.7 for examples of response actions.

Yes: GO TO STEP 2.7 where the Owner/Operator takes necessary response actions according to the Site Classification requirements shown in Tier 1 (Utah Department of Environmental Quality, DERR, 1997).

No: GO TO STEP 2.22 for submittal of the Tier 2 Risk Assessment and CAP.

Step 2.22: Owner/Operator Submits Tier 2 Risk Assessment Report and a Corrective Action Plan

For all of the options, after the Owner/Operator completes a Tier 2 Risk Assessment, they must submit the Tier 2 Risk Assessment report. The contents of the Tier 2 Risk Assessment report are specified in Section 3 of this document. The Tier 2 Risk Assessment report documents all findings, conclusions and recommendations.

A CAP must be submitted for all affected areas where the Owner/Operator determines that cleanup to appropriate levels is reasonable, or if any SSCL values are exceeded for a complete exposure pathway. The Executive Secretary (UST) must review and approve the CAP prior to its implementation.

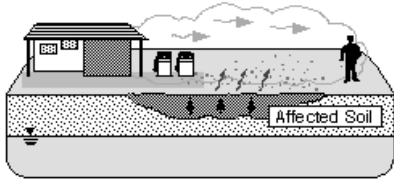
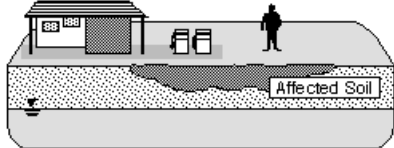
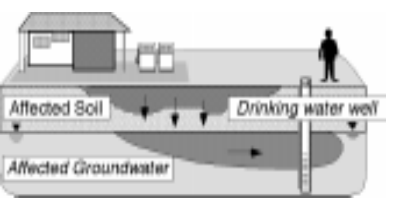
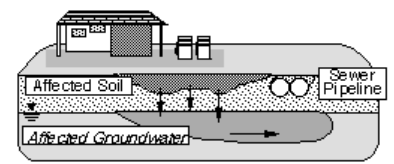
The Owner/Operator must submit the CAP in a format specified in the CAP guide issued by the DERR and included in Appendix E-1. The CAP:

- Evaluates, identifies, and describes all appropriate or applicable cleanup technologies for their ability to achieve the applicable performance standard for the exposure pathway(s) of concern, and;
- Provides detailed design and construction information regarding the selected corrective action method.

For each complete exposure pathway for which a SSCL is exceeded, the selected corrective action must achieve minimum performance standards. Performance standards, which are identified in Figure 2-4, are protective criteria that serve to reduce risk posed to current and future receptors. For the pathways listed on Figure 2-4, these performance standards fall into two general categories:

- *Human Health Protection:* For human health exposure pathways, including air, soil, or groundwater exposures, the applicable performance standard involves reduction of contaminant concentrations at the POE to safe levels, as defined by the applicable TER limits. Reduction to safe levels can be achieved by removal or treatment of affected soil and/or groundwater exceeding the applicable pathway SSCL values, or by use of appropriate exposure control measures (e.g., environmental controls) to prevent contaminant migration to the POE at levels exceeding the specified TER limits.
- *Subsurface Utility Protection:* For subsurface utilities such as sewer lines, water mains and telephone lines, practical measures must be applied to prevent physical damage to the utility by soil or groundwater contaminants, including non-aqueous phase liquids (NAPL); accumulation of explosive vapors at a level exceeding 20% of the lower explosive limit (LEL) in the utility air space, and (3) migration of contaminated fluids or vapors via the utility line or associated backfill. In all cases, NAPLs present in the groundwater system must be removed to the extent practicable. For protection of subsurface utilities, SSCL values *cannot* be derived or applied. Rather,

Figure 2-4: Risk Management Options for Complete Exposure Pathways

Exposure Pathway and Remedy Performance Standard		EXAMPLES OF RESPONSE ACTIONS FOR:	
		Current Exposure	Potential Exposure
	Air Exposure Prevent exceedance of applicable risk limits resulting from vapor or dust inhalation.	<ul style="list-style-type: none">• Soil Removal or Treatment: Remove and/or treat affected soils to achieve applicable Tier 1 Criteria or Tier 2 SSCLs.• Engineering Controls: Control vapor or dust release by soil stabilization, encapsulation, or surface cover measures.	<ul style="list-style-type: none">• Engineering Controls: Maintain or augment existing surface cover to prevent soil vapor and dust release; install fencing to restrict access.
	Soil Exposure Prevent exceedance of applicable risk limits resulting from human exposure via incidental soil ingestion or dermal contact	<ul style="list-style-type: none">• Soil Removal or Treatment: Remove and/or treat affected soils to achieve applicable Tier 1 Criteria or Tier 2 SSCLs.• Engineering Controls: Prevent soil ingestion or dermal contact by soil encapsulation of surface cover measures.	<ul style="list-style-type: none">• Engineering Controls: Maintain or augment existing surface cover to prevent soil contact.
	Groundwater Ingestion Prevent exceedance of drinking water limits in water supply wells completed within underlying water-bearing strata.	<ul style="list-style-type: none">• GW Removal or Treatment: Remove and/or treat affected GW to achieve applicable Tier 1 Criteria or Tier 2 SSCLs.• Engineering Controls: Install physical or hydraulic barrier to prevent GW plume migration to POE.	<ul style="list-style-type: none">• GW Natural Attenuation: Conduct natural attenuation monitoring as needed to confirm plume stability or reduction.
	Subsurface Utilities Prevent property damage, explosive vapor condition, and contaminant migration via subsurface utility corridor. Remove non-aqueous phase liquids (NAPLs) to extent practicable.	<ul style="list-style-type: none">• Soil or GW Removal or Treatment: Remove and/or treat affected soils and GW impacting subsurface utility.• Engineering Controls: Use physical barrier, vapor control measures, etc., to prevent impacts on subsurface utilities.	<ul style="list-style-type: none">• Construction Notice: Define zone subject to special construction measures.• GW Natural Attenuation: Conduct natural attenuation monitoring as needed to confirm plume stability or reduction.
NOTES: 1) For all current or potentially complete exposure pathways identified in the initial pathway screening and in Tier 2 Options 1 through 4, response actions will be required to protect public health and the environment. Appropriate remedial measures must be developed on a site-specific basis in accordance with CAP requirements. As noted in above examples, effective risk management may involve more frequent use of active removal or treatment measures for <i>current</i> exposures than for <i>potential</i> future exposures. Response measures listed above are for example purposes only. 2) Current Exposure: Pathway is complete and may pose current, ongoing exposure in excess of applicable limits. Potential Exposure: Pathway is complete, but exposure is not presently occurring because of current site use and/or existing control measure such as pavement or fencing. 3) GW = Groundwater POE = Point of Exposure NAPL = Non-Aqueous Phase Liquid SW = Surface water Tier 1 Criteria = Utah's Tier 1 Screening Levels and distance to receptors criteria SSCL = Site-Specific Cleanup Level			

direct inspections and/or measurements such as soil vapor surveys are conducted to identify potential impacts, and appropriate measures are implemented as needed to meet the applicable performance standards.

The corrective action strategy selected to achieve these performance standards will depend in part on the relative immediacy of the potential impact associated with each pathway of concern, as shown in Figure 2-4. For *current* exposures, active removal/treatment measures or installation of engineering controls may be required to achieve immediate reduction of exposure concentrations. Examples of response actions for both current and potentially complete exposure pathways are provided on Figure 2-4.

The CAP submittal must evaluate the relative performance and feasibility of available cleanup technologies and justify selection of the proposed remedy. Further detail regarding the scope and format of the CAP is provided in Appendix E-1 of this document.

GO TO STEP 2.23 to submit a request for no further action.

Step 2.23: Owner/Operator Requests No Further Action

After the Owner/Operator completes a Tier 2 Risk Assessment, they must submit a risk assessment report, if not previously submitted as part of Step 2.22. The Tier 2 Risk Assessment Report documents their findings, conclusions and recommendations. If a corrective action plan was submitted, then the Owner/Operator needs only to submit the corrective action report which details the cleanup results by providing appropriate progress, monitoring or confirmation reports. The Owner/Operator may request that no further action be taken based on achieving SSCLs and ALs for AMPs, if applicable. Owners/Operators should submit a written request for no further action to the Executive Secretary (UST).

GO TO STEP 2.24 where the DERR determines if further action is required based on the Cleanup Standards Policy.

Step 2.24: DERR Evaluation: Are the Cleanup Criteria Met?

The DERR evaluates the progress and monitoring reports based on the Cleanup Criteria required by the Cleanup Standards Policy. Those criteria are:

- Source elimination through removal or control;
- Current or potential impact of the contamination on public health;
- Current or potential impact of the contamination on the environment;
- Economic considerations and cost-effectiveness of cleanup options, and;
- Technology available for use in cleanup.

As stated in the CAP guide in Appendix E-1, public notification is required for any CAP prior to actual implementation. However, in the case of Tier 2 Risk Assessments, these public notification requirements are postponed until after the risk assessment is completed and the final Risk Assessment report is reviewed by the Executive Secretary (UST). The public notification requirements in the case of Tier 2 Risk Assessments are made by the Executive Secretary (UST) on a site-specific basis and must be completed prior to site closure considerations. The Owner/Operator is required to notify the potentially affected public of the preliminary acceptance of the conclusions and recommendations of the risk assessment. All relevant comments received during the public comment period will be considered, and addressed as needed, on a case-by-case basis by the Executive Secretary (UST).

Yes: GO TO STEP 2.27 where the Executive Secretary (UST) issues the Owner/Operator a no further action letter.

No: GO TO STEP 2.25 where the Executive Secretary (UST) issues the Owner/Operator a letter identifying further work needed.

Step 2.25: Executive Secretary (UST) Issues the Owner/Operator Letter Identifying Further Work Needed

If the requirements of the Cleanup Criteria have not been met, the Executive Secretary (UST) issues the Owner/Operator a letter identifying work needed to meet those requirements. The letter identifies the options available to the Owner/Operator that are necessary to enable the DERR to close the case file and require no further action. Available options generally include continued cleanup to applicable contaminant levels, performing environmental monitoring or performing a risk assessment.

Although the DERR cannot require or enforce the implementation of environmental controls, Owners/Operators may propose voluntary environmental controls if it is useful for closing the case file with contamination in place. Environmental controls are measures that are taken to limit or reduce the likelihood of receptors being exposed to contamination. Common forms of environmental controls may include engineering controls such as paving, fencing, vapor barriers, vapor extraction, and institutional controls such as environmental notice, deed restrictions, land use and zoning restrictions, and environmental monitoring.

The Owner/Operator may propose new cleanup levels if the approved CAP is no longer cost-effective or technically capable of achieving the original cleanup levels. The Cleanup Criteria again must be evaluated and must demonstrate that new cleanup levels are protective of receptors via all exposure pathways to applicable MCLs, the TER or other applicable standards.

GO TO STEP 2.26. If the SSCLs and ALs for AMPs, if applicable, are not achieved, or if receptors are at risk of exposure to concentrations greater than MCLs, the TER or other applicable standards, cleanup according to an approved CAP must continue or be implemented until the SSCLs are achieved.

Step 2.26: Has the Owner/Operator Completed the Additional Work, Environmental Controls and/or Monitoring?

The Owner/Operator is responsible for completing appropriate work for achieving the cleanup levels and meeting the requirements of the Cleanup Criteria (see Step 2.24). The DERR evaluates all data to determine if the work performed is successful in meeting the requirements of the Cleanup Criteria.

To confirm satisfactory completion of the corrective action, a compliance monitoring program may be required for all affected media that were addressed by the CAP. Compliance monitoring, or confirmation sampling, typically involves sampling and testing of a representative number of locations on an established schedule to identify either:

- Any remaining contaminant levels exceeding established SSCLs or ALs, if applicable, or;
- New site conditions that may require additional corrective action.

For soils, confirmation sampling at representative locations and depths will be required. For groundwater, multiple sampling episodes may be required to demonstrate the effectiveness of the groundwater corrective action effort.

General guidelines for design and implementation of compliance monitoring for soil and groundwater cleanups are provided below. Once sufficient data have been provided to demonstrate satisfactory completion of the corrective action program, the Owner/Operator may request no further action at the site. See Step 1.22 and Step 2.23 for the procedures leading to this request.

Soil Compliance Monitoring Specifications

Soil confirmation sampling is required upon completion of soil removal or other treatment actions to confirm attainment of specified cleanup goals throughout the affected soil source zone. For corrective actions involving containment measures, compliance monitoring must address possible migration pathways (e.g., air or groundwater impacts at the POE or at AMPs) rather than the affected soil zone itself.

- **Duration and Frequency:** Soil confirmation sampling typically involves one or more sampling events to confirm compliance with cleanup goals. If data evaluation indicates an exceedance of applicable concentration limits, sampling must be repeated following further cleanup activities.
- **Number and Location of Soil Sampling Points:** A sufficient number of soil samples should be collected from representative locations and depths to confirm compliance with applicable cleanup goals throughout the area of affected soils. As needed, sampling should be conducted at the perimeter of the engineering control zone (in soil, air, or groundwater) to confirm compliance with applicable action levels. The number of samples will depend on the size of the source area and the observed variability of constituent concentrations. On a case-by-case basis, DERR may increase the minimum number of samples based on the size and nature of the soil removed or treated.
- **Soil Analytical Methods:** Soil samples should be analyzed in the laboratory for all COCs potentially associated with the UST release. Typically, these will include BTEXN, MTBE and TPH. For a complete list of required COCs based on product type, see “Table of Analytical Methods for Sampling” in the CAP guide in Appendix E-1.

On a case-by-case basis, DERR may allow analysis for only selected constituents from this list if prior analyses have shown certain constituents to be absent or at concentrations below applicable cleanup standards in the affected soil zone. Analytical methods should conform with applicable EPA protocols and must provide method detection limits that are lower than the applicable cleanup goal or AL for each COC analyzed.

Groundwater Compliance Monitoring Specifications

Groundwater sampling and testing in the plume source area (POC) and/or down-gradient POE and AMP locations will be required to confirm the effectiveness of groundwater remedies. Figure 2-2 illustrates optional groundwater monitoring locations and applicable concentration limits.

- **Duration and Frequency:** The groundwater compliance monitoring program must be sufficiently long to confirm that applicable concentration limits will not be exceeded at any future time. The program duration is determined by the DERR on a case-by-case basis. For this purpose, COC concentrations in the groundwater at the selected monitoring locations must be shown to have reached stable (maximum) levels or to be diminishing over time. The time required to reach maximum levels will be a function of the mobility of the COCs in the groundwater system (constituent seepage velocity), the distance of the compliance monitoring point from the source area, and the age of the release.

Current DERR guidelines generally require a minimum of two consecutive quarterly monitoring episodes confirming compliance with cleanup standards. However, on a case-by-case basis, the DERR may require that the minimum compliance monitoring period be extended to ensure measurement of stable plume conditions.

- **Number and Location of Groundwater Sampling Points:** For CAPs implemented without a Tier 2 Risk Assessment, the entire affected groundwater area must meet applicable Tier 1 criteria or groundwater MCLs. For CAPs based on a Tier 2 Risk Assessment, the groundwater SSCL represents a source-area COC

concentration which, if left in place, will be protective of water usage at down-gradient POEs. These SSCL values must be achieved at the groundwater POC, corresponding to the groundwater source area (i.e., point of plume release or current maximum concentrations; see Figure 2-2).

To confirm adequate contaminant plume corrective action at the POC, groundwater sampling points should monitor the source area of the plume. The measured concentrations should be compared to the applicable cleanup goals. These include Tier 1 criteria or MCLs if no Tier 2 Risk Assessment is conducted, or SSCL values if a Tier 2 Risk Assessment has been conducted. For sites where groundwater monitoring directly at the POC is impractical, monitoring of only down-gradient points may suffice.

AMPs must be established down-gradient of the POC, at a location that is at least one-year of plume travel time upstream of the applicable POE. AMPs are used to confirm remediation of the down-gradient portion of the plume and to provide an early warning of any potential impacts on a down-gradient receptor.

- For CAPs *not* based on a Tier 2 Risk Assessment, COC levels measured at the AMPs must be less than applicable Tier 1 criteria or MCLs.
- If a Tier 2 Risk Assessment *has* been conducted, COC concentrations at AMPs must be shown to be less than applicable ALs established as discussed in Figure C-1 of Appendix C of this document.

The number of groundwater sampling locations should be sufficient to account for the variability of COC concentrations within the groundwater flow regime and the variability in vertical groundwater fluctuation, groundwater flow direction, hydraulic gradient, depth to groundwater, and groundwater elevation down-gradient of the source point. For evaluation of concentrations at the source area, one sampling location often is adequate to detect maximum plume concentrations. Down-gradient monitoring points should be located near the centerline of the plume because two or more monitoring locations may be required to define the plume centerline and representative COC concentrations in the plume.

- **Groundwater Analytical Methods:** Groundwater samples should be analyzed in the laboratory for all COCs potentially associated with the UST release. Typically, these will include BTEXN, MTBE and TPH. For a complete list of required COCs based on product type, see “Table of Analytical Methods for Sampling” in the CAP guide in Appendix E-1.

On a case-by-case basis, the DERR may allow analysis for only selected constituents from this list if prior analyses have shown certain constituents to be absent or at concentrations below applicable cleanup standards in the affected groundwater area. Analytical methods should conform with applicable EPA protocols and must provide method detection limits that are lower than the applicable cleanup goal or action level for each COC analyzed.

- Yes:** GO TO STEP 2.27 if the Owner/Operator completes the required work and the Cleanup Criteria are satisfied. The Executive Secretary (UST) will issue a no further action letter.
- No:** GO TO STEP 2.25 if the Owner/Operator does not complete the required work and the Cleanup Criteria are not satisfied in accordance with Step 2.25. The Executive Secretary (UST) issues the Owner/Operator correspondence stating that the case file cannot be closed out until the required work for achieving no further action is complete.

Step 2.27: No Further Action

If the cleanup levels have been met and the Cleanup Criteria have been satisfied, the Executive Secretary (UST) of

the Utah Solid and Hazardous Waste Control Board will issue a no further action letter to the Owner/Operator based on the current land use at the site. However, if future evidence indicates contamination at or emanating from a site, further corrective action may be required.

3.0 Procedures and Format for the Tier 2 Risk Assessment Report

3.1 Introduction

This section provides the procedures and format for performing and presenting a Tier 2 Risk Assessment for each of the four options available for Utah's Tier 2 Risk Assessment process. This format is intended to provide consistency and help expedite Tier Risk Assessment reviews by the DERR.

Table 3-1 shows the exposure media and transport mechanisms that must be evaluated *for each complete exposure pathway and for each option*. Complete the Site Conceptual Exposure Model (Worksheet #3 of Appendix A). Follow the procedures outlined in this section to calculate and derive SSCLs for each complete exposure pathway.

Table 3-1: Exposure Evaluation Chart for Residential and Commercial/Industrial Land Uses

EXPOSURE MEDIUM	AIR EXPOSURE PATHWAY			GROUNDWATER EXPOSURE PATHWAY		SOIL EXPOSURE PATHWAY	
	Vapor Intrusion to Indoor Air	Vapor Intrusion to Outdoor Air	Vapor Inhalation & Dust Ingestion	Groundwater Ingestion	Soil Leaching to Groundwater (ingestion)	Ingestion and Dermal Contact	Construction Worker ^a Dermal Contact and Ingestion
Groundwater	✓	✓	na	✓	na	na	na
Subsurface Soil	✓	✓	na	na	✓	na	na
Surface Soil	na	na	✓	na	✓	✓	✓

^a Subsurface soil excavated during construction is considered surface soil.

3.2 Tier 2 Risk Assessment Report Format for All Options

Submit the final Tier 2 Risk Assessment report to the DERR in the order shown below. Complete each of the risk assessment worksheets found in Appendix A, data requirements in Appendix B, and the calculations from Appendix C.

Electronic versions of all of the worksheets and forms are available on the DERR's Internet site at <http://www.deq.state.ut.us/eqerr/errhmpg.htm>. Electronic forms are provided in Word Perfect version 6.0 and Excel 97.

All Tier 2 Risk Assessment reports must be submitted to the DERR in hard (paper) copy. Electronically transferred submittals or handwritten reports will not be accepted.

If the Owner/Operator chooses to prepare the Tier 2 Risk Assessment report from the electronic forms, the length of each item can be increased or decreased, based on the amount of information presented. *However, none of the items may be deleted.* If a particular item does not apply, enter "Not Applicable" in the response space. Similarly, extra pages can be added if the report is prepared using the paper versions of the forms included in the appendices, and items that do not apply should be marked "Not Applicable" but must not be deleted.

Appendix A

- **Worksheet #1, Risk Assessment Report.** Indicate what option is used. Use Worksheet #1 to:
 - Discuss site history, cause(s) of release(s), the contaminant source control measures, and the abatement measures taken.
 - Show calculated SSCLs and compare them to source concentrations. Show and discuss NAFs for Options 2 through 4.
 - Describe and discuss all current and potentially complete exposure pathways, and potential risks to receptors.
 - Ensure all other requirements of the Cleanup Standards Policy are met. A copy of this document is provided in Appendix F.
- **Worksheet #2, Data Requirements.** Worksheet #2 shows the permissible values for site-specific parameters and the permissible exposure parameter values. Enter the site-specific value for each parameter shown in the spaces provided in the worksheet. Site-specific supporting raw data such as soil boring logs, analytical results are to be included in Appendix B.
- **Worksheet #3, Site Conceptual Exposure Model.** Follow the instructions to complete this worksheet.
- **Worksheets #4a through 4e.** Complete these worksheets, as needed, if determining plume stability and mass balance are applicable.
 - **Worksheet #4a, Plume Stability Results.** Discuss the results of the plume stability and mass balance calculations.
 - **Worksheet #4b, Mass Calculations for Initial and Ending Dissolved Phases.** Calculate contaminant mass in the dissolved plume for different sampling events over time.
 - **Worksheet #4c, Mass Calculations for Initial and Ending Adsorbed Phases.** Calculate contaminant mass in the adsorbed plume for different sampling events over time.

- **Worksheet #4d, Determining Percent Decrease in Dissolved COC Concentrations in Contaminant Plumes.** Calculate the average reduction or increase of dissolved contaminant concentrations for different sampling events over time.
- **Worksheet #4e, Statistical Evaluation of Plume Stability.** Statistically determine the reduction or increase of dissolved contaminant concentrations for different sampling events over time.

Appendix B

- Attach the specified required data in the order shown in Appendix B. Data include site maps, cross-sections, graphs, tabulated laboratory analytical data of all measured parameters, hydrographs, boring logs, soil types, and other site-specific data required for the applicable option. Applicable portions of other reports may be attached to Appendix B.

Appendix C

Calculations for SSCLs for Options 1 through 4, and SSCLs and ALs for AMPs for Options 3 and 4:

- Attach calculation results to Appendix C. For transient modeling (Options 3 and 4 only) attach input, output, graphics, and other modeling-related items to Appendix C.

3.3. Option 1 Procedures

Option 1 may be appropriate when the Tier 1 criteria for soil are exceeded at a site. The Owner/Operator may perform an Option 1 risk assessment by using site-specific data to calculate Option 1 SSCLs. Performing an Option 1 Risk Assessment and calculating Option 1 SSCLs are permissible if all of the following conditions are met:

- Source has been eliminated by removal or control.
- The extent and degree of contamination are defined.
- The contaminant plume (soil and/or groundwater) is stable or diminishing.
- No off-site receptors are impacted or threatened via complete exposure pathways.
- Appendix A Worksheets #1, #2 and #3, and Appendices B and C are completed according to their specified requirements.

PROCEDURES FOR CALCULATING OPTION 1 SSCLs

Data requirements for Option 1 are shown in Worksheet #2 of Appendix A. Option 1 is a two-step process that involves the Owner/Operator calculating Option 1 SSCLs and presenting the Option 1 Risk Assessment.

Step 1. Solve the exposure and cross-media transport equations in Table C-1 of Appendix C for each complete exposure pathway (air, soil and groundwater). Determine complete exposure pathways by reviewing the SCEM in Worksheet #3. Calculate the SSCLs for individual COCs, such as BTEXN, MTBE, and other contaminants of concern if applicable. To solve the equations, use the site-specific and exposure parameter values for Option 1 shown in Worksheet #2 of Appendix A, and the chemical property and toxicity values shown in Tables C-2 through C-5 of Appendix C. Commercially available electronic spreadsheets may also be used to solve the equations.

NOTE: It is not permissible to compare the calculated SSCLs to the Permissible Exposure Limits (PELs) because PELs are intended for acute rather than chronic exposure scenarios. In addition, PELs apply to working conditions in which workers are knowingly exposed to contamination and have been OSHA-trained.

- a. Solve the equations for RBSLs for the applicable on-site land use setting and for on-site receptors only for all complete exposure pathways. The calculated Option 1 SSCLs are equal to the RBSLs because, for Option 1, only on-site receptors are present and there is therefore no NAF.
- Step 2. Determine if the highest on-site contaminant concentrations exceed the calculated SSCLs. To determine if the SSCLs are exceeded, compare the maximum observed on-site contaminant concentrations of individual constituents to the calculated or final Option 1 SSCLs for all exposure pathways. ***The lowest contaminant concentrations that are calculated for a complete exposure pathway represent the final Option 1 SSCLs.*** If the Option 1 SSCLs are exceeded, go to Option 2 or submit a CAP to clean up the contamination to the calculated Option 1 SSCLs or other applicable standards.

3.4. Option 2 Procedures

Option 2 may be appropriate when the Tier 1 criteria for soil and/or groundwater are exceeded. Option 2 is useful when on-site or off-site receptors are present, or if on-site receptors are some distance from the source area. The Owner/Operator may perform an Option 2 risk assessment by using site-specific data to calculate SSCLs. Performing an Option 2 Risk Assessment and calculating Option 2 SSCLs are permissible if all of the following conditions are met:

- The source has been eliminated by removal or control.
- The extent and degree of soil and groundwater contamination are defined.
- The contaminant plume is stable or diminishing.
- One year of quarterly monitoring data have been collected and adequately support evaluation of whether the contaminant plume is stable or diminishing, and the estimation of an empirical NAF and/or contaminant half-lives, if applicable.
- Appendix A Worksheets #1, #2, #3 and #4a through #4e, and Appendices B and C are completed according to their specified requirements.

PROCEDURES FOR CALCULATING OPTION 2 SSCLs

Site-specific data requirements for Option 2 are shown in Worksheet #2 of Appendix A. Option 2 is a three-step process that involves the Owner/Operator calculating Option 2 SSCLs and presenting the Option 2 Risk Assessment.

- Step 1. Evaluate the stability condition of the groundwater plume using Worksheets #4a through #4e. If the groundwater plume is stable or diminishing, derive final groundwater SSCLs according to Step 2 below using an empirical NAF. If the plume is not stable or diminishing, Option 2 does not apply and the user should submit a CAP to clean up the contamination to applicable standards, or proceed to Option 3 or 4.
- Step 2. Solve the exposure and cross-media transport equations in Table C-1 of Appendix C for the applicable on-site and off-site land use settings, and for each complete exposure pathway (air, soil and groundwater). Determine complete exposure pathways by reviewing the SCEM in Worksheet #3. Calculate the SSCLs for individual COCs, such as BTEXN, MTBE, and other contaminants of concern if applicable. To solve the equations, use the site-specific and exposure parameter values for Option 2 shown in Worksheet #2 of Appendix A, and the chemical property and toxicity values shown in Tables C-2 through C-5 of Appendix C. Commercially available electronic spreadsheets may also be used to solve the equations.

NOTE: It is not permissible to compare the calculated SSCLs to the PELs because PELs are intended for acute rather than chronic exposure scenarios. In addition, PELs apply to working conditions in which workers are knowingly exposed to contamination and have been OSHA-trained.

- a. For on-site receptors only, the SSCLs are equal to the RBSLs.
 - b. For off-site receptors or receptors located some distance from the source, calculate the NAF using Equation C.25 in Appendix C Table C-1. Multiply NAF by the calculated RBSLs to derive final Option 2 SSCLs. Information on NAFs and their derivation is provided Section 2.2.
- Step 3. Determine if the highest on-site contaminant concentrations exceed the calculated SSCLs. To determine if the SSCLs are exceeded, compare the maximum observed on-site contaminant concentrations of individual constituents to the calculated or final Option 2 SSCLs for all exposure pathways. ***The lowest contaminant concentrations that are calculated for a complete exposure pathway represent the final Option 2 SSCLs.*** If the Option 2 SSCLs are exceeded, go to Option 3 or submit a CAP to clean up the contamination to the calculated Option 2 SSCLs.

3.5. Option 3 Procedures

Option 3 may be appropriate for cases where Option 2 SSCLs are exceeded, or at sites where contaminant plumes are not stable or expanding. The benefits of performing an Option 3 Risk Assessment may be realized if Owners/Operators cannot achieve cleanup to Option 2 SSCLs for a reasonable cost, and if there is sufficient site-specific data for deriving Option 3 SSCLs for the source area and Action Levels (ALs) for Alternate Monitoring Points (AMPs).

The Owner/Operator may perform an Option 3 Risk Assessment by using site-specific data to calculate preliminary SSCLs and performing transient modeling to derive final Option 3 SSCLs. Deriving Option 3 SSCLs and ALs is possible when the site-specific data requirements shown in Worksheet #2 (Appendix A) are met, when the transient modeling accurately reflects site conditions, and when the transient modeling indicates when SSCLs will be achieved.

Utah has modified the ASTM (1995) method for deriving Option 3 SSCLs. Utah's method *excludes* evaluation of the cumulative effects of contamination on receptors because of the highly conservative nature of the exposure and cross-media transport assumptions that are used in the standard equations (see Appendix C, Tables C-1, C-2 and C-3). The DERR's decision to exclude cumulative effects is also supported by the conservative requirements of the Cleanup Standards Policy that all receptors be protected to applicable MCLs, the TER or other applicable standards.

Option 3 is more complex than Options 1 and 2 because it *includes* provisions for performing analytical transient contaminant fate and transport modeling. A minimum of two years of quarterly environmental monitoring is required to enable Owners/Operators to perform accurate and representative mass balance calculations and transient contaminant fate and transport modeling.

Performing an Option 3 Risk Assessment and deriving Option 3 SSCLs are permissible if all of the following conditions are met:

- The source has been eliminated by removal or control.
- The extent and degree of soil and groundwater contamination are defined.
- Two years of quarterly monitoring have been performed and are sufficient to define the contaminant plume as stable, diminishing or expanding.
- Appendix A Worksheets #1, #2 #3 and #4a through #4e, and Appendices B and C are completed according to their specified requirements.
- Transient analytical modeling is performed and produces results that are reasonable and are able to match the actual contaminant plume configuration during the monitoring period.

PROCEDURES FOR DERIVING OPTION 3 SSCLs

Data requirements for Option 3 are identified in Worksheet #2 and must be met prior to beginning the Option 3 Risk Assessment. The Option 3 SSCLs and ALs represent contaminant concentrations that must be achieved for any complete exposure pathway. If the preliminary SSCLs are exceeded or if the plume is expanding, final SSCLs may be derived using transient analytical modeling to estimate the transport and fate of the contamination in space and time. The Owner/Operator derives Option 3 SSCLs and ALs for soil and groundwater to protect on-site and off-site receptors using the following three-step process:

Step 1: Calculate preliminary Option 3 SSCLs for all complete exposure pathways according to the SCEM in Worksheet #3 of Appendix A. Calculate the SSCLs using the RBSL equations shown in Table C-1 of Appendix C. Commercially available electronic spreadsheets may also be used to solve the exposure and transport equations and calculate *preliminary* SSCLs. To solve the equations, use the site-specific parameter values for Option 3 and the exposure parameter values shown in Worksheet #2 of Appendix A, and the chemical property and toxicity values shown in Tables C-2 through C-5 of Appendix C.

NOTE: It is not permissible to compare the calculated SSCLs to the PELs because PELs are intended for acute rather than chronic exposure scenarios. In addition, PELs apply to working conditions in which workers are knowingly exposed to contamination and have been OSHA-trained.

- a. Calculate preliminary Option 3 SSCLs by solving the exposure and cross-media transport equations in Table C-1 for the applicable on-site and, if applicable, off-site land use settings and receptors.
- b. For off-site receptors, or receptors located some distance from the source, calculate the NAF using Equations C.22 through C.25 in Table C-1. Multiply the NAF by the calculated SSCLs to derive preliminary Option 3 SSCLs. Information on the NAF is provided in Section 2.
- c. Calculate the locations for AMPs and the ALs required for the AMPs using Figure C-1 in Appendix C.

Preliminary SSCLs are used to determine appropriate SSCLs if all of the contaminant mass is available for each exposure pathway. Preliminary SSCLs are conservative because they assume that all of the contaminant mass is applied to each equation. If there is reason to believe that contamination is distributed through more than one medium and/or exposure route. Option 3 SSCLs may be derived using transient modeling to more accurately determine SSCLs that are protective of receptors to the TER.

- Step 2: Determine if the contaminant concentrations exceed the calculated preliminary SSCLs for the source area, or ALs for AMPs. This involves comparing the maximum observed contaminant concentrations of individual constituents to the calculated Option 3 SSCLs and ALs for all complete exposure pathways.
- Step 3: For each exposure pathway and COC that exceeds a preliminary SSCL or AL that was calculated from the Table C-1 equations, perform transient analytical modeling to derive final SSCLs. The final SSCLs may be more accurate for determining exposure to human health and the environment because they consider effects resulting from contaminant partitioning in space and time, and consider the potential for multiple exposure pathways and receptors. The results of the Option 3 Risk Assessment include:
- The allowable SSCLs for each exposure pathway and COC, and;
 - The duration and fate of the COCs if their applicable preliminary SSCLs are exceeded.

The final SSCLs and ALs are the contaminant concentrations that are expected to be protective of POEs to the TER. The modeling must show that the SSCLs will achieve the ALs at the AMPs and TER concentrations at the POE. The DERR uses the transient models listed in Section 2 for Option 3 analyses. However, other models also are appropriate and may be used.

3.6. Option 4 Procedures

Option 4 may be appropriate for cases where Option 3 SSCLs are exceeded. Refer to the introduction to Section 2 for the criteria to be used to determine if an upgrade to Option 4 is recommended. The Owner/Operator may perform an Option 4 Risk Assessment by using site-specific data to calculate SSCLs and performing transient modeling to derive final Option 4 SSCLs. Deriving Option 4 SSCLs and ALs is possible when the site-specific data requirements shown in Worksheet #2 (Appendix A) are met, when the transient modeling accurately reflects site conditions, and when the transient modeling indicates when SSCLs will be achieved.

Utah has modified the ASTM (1995) method for deriving Option 4 SSCLs. Utah's method *excludes* evaluation of the cumulative effects of contamination on receptors because of the highly conservative nature of the exposure and cross-media transport assumptions that are used in the standard equations (see Appendix C, Tables C-1, C-2 and C-3). The DERR's decision to exclude cumulative effects is also supported by the conservative requirements of the Cleanup Standards Policy that all receptors be protected to applicable MCLs, the TER or other applicable standards.

Option 4 is more complex than Options 1 through 3 because it *includes* provisions for performing transient analytical and transient numerical contaminant fate and transport modeling. A minimum of five years of quarterly environmental monitoring is required to enable Owners/Operators to perform accurate and representative mass balance calculations and transient contaminant fate and transport modeling.

Performing an Option 4 Risk Assessment and deriving SSCLs are permissible if all of the following conditions are met:

- The source has been eliminated by removal or control.
- The extent and degree of soil and groundwater contamination are defined.
- Five years of quarterly monitoring have been performed and are sufficient to the contaminant plume as stable, diminishing or expanding.
- Appendix A (Worksheets #1, #2 #3 and #4a through #4e), and Appendices B and C are completed according to their specified requirements.
- Transient analytical modeling is performed and produces modeling results that are reasonable and are able to match the actual contaminant plume configuration during the monitoring period.

PROCEDURES FOR DERIVING OPTION 4 SSCLs

Data requirements for Option 4 are identified in Worksheet #2 and must be met prior to beginning the Option 4 Risk Assessment. The Option 4 SSCLs and ALs represent contaminant concentrations that must be achieved for any complete exposure pathway. If the preliminary SSCLs are exceeded or if the plume is expanding, final SSCLs may be derived using transient analytical modeling to estimate the transport and fate of the contamination in space and time. The Owner/Operator derives Option 4 SSCLs and ALs for soil and groundwater to protect on-site and off-site receptors using the following three-step process:

Step 1: Calculate preliminary Option 4 SSCLs for all complete exposure pathways according to the SCEM in Worksheet #3 of Appendix A. Calculate the SSCLs using the RBSL equations shown in Table C-1 of Appendix C. Commercially available electronic spreadsheets may also be used to solve the exposure and transport equations and calculate *preliminary* SSCLs. To solve the equations, use the site-specific parameter values for Option 4, the exposure parameter values shown in Worksheet #2 of Appendix A, and the chemical property and toxicity values shown in Tables C-2 through C-5 of Appendix C.

NOTE: It is not permissible to compare the calculated SSCLs to the PELs because PELs are intended for acute rather than chronic exposure scenarios. In addition, PELs apply to working conditions in which workers are

knowingly exposed to contamination and have been OSHA-trained.

- a. Calculate preliminary Option 4 SSCLs by solving the exposure and cross-media transport equations in Table C-1 for the applicable on-site and, if applicable, off-site land use settings.
- b. For off-site receptors, or receptors located some distance from the source, calculate the NAF using Equations C.22 through C.25 in Table C-1. Multiply the NAF by the calculated SSCLs to derive preliminary Option 4 SSCLs. Information on NAFs and their derivation is provided in Section 2.
- c. Calculate the locations for AMPs and the ALs required for the AMPs using Figure C-1 in Appendix C.

Preliminary SSCLs are used to determine appropriate SSCLs if all of the contaminant mass is available for each exposure pathway. Preliminary SSCLs are conservative because they assume that all of the contaminant mass is applied to each equation. If there is reason to believe that contamination is distributed through more than one medium and/or exposure route, Option 4 SSCLs may be derived using transient modeling to more accurately determine SSCLs that are protective of receptors to the TER.

- Step 2: Determine if the contaminant concentrations exceed the calculated preliminary SSCLs for the source area, or ALs for AMPs. This involves comparing the maximum observed contaminant concentrations of individual constituents to the calculated Option 4 SSCLs and ALs for all complete exposure pathways.
- Step 3: For each exposure pathway and COC that exceeds a preliminary SSCL or AL that was calculated from the Table C-1 equations, perform transient analytical and transient numerical modeling to derive final SSCLs. The final SSCLs may be more accurate for determining exposure to human health and the environment because they consider effects resulting from contaminant partitioning in space and time, and consider the potential for multiple exposure pathways and receptors. The results of an Option 4 Risk Assessment include:
- The allowable SSCLs for each exposure pathway and COC, and;
 - The duration and fate of the COCs if their applicable preliminary SSCLs are exceeded.

The final SSCLs and ALs are the contaminant concentrations that are expected to be protective of POEs to the TER. The modeling must show that the SSCLs will achieve the ALs at the AMPs and TER concentrations at the POE. The DERR uses the transient models listed in Section 2 for Option 4 analyses. However, other models also are appropriate and may be used.

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APPENDIX A

Tier 2 Risk Assessment Worksheets

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GENERAL INSTRUCTIONS FOR COMPLETING THE TIER 2 RISK ASSESSMENT WORKSHEETS

Introduction

Utah's Tier 2 Risk Assessment process requires completing Worksheets #1 through #3, and, if applicable, Worksheets 4a through 4e in this Appendix A. These worksheets aid in performing and reporting Tier 2 Risk Assessments in a consistent manner and ensure that all requirements of the Cleanup Standards Policy are met. The information provided in the worksheets enables the Owner/Operator and the DERR to evaluate the need for further action at a site.

Completing the Tier 2 Worksheets

Each of the following worksheets contains instructions for completing the data entry fields. All data entry fields must be complete. References to other documents will not be accepted. Electronic version of all of the worksheets and forms are available on the DERR's Internet site at <http://www:deq.state.ut.us/eqerr/errhmpg.htm>. Electronic forms are provided in Word Perfect version 6.0. Handwritten forms or electronic submittals will not be accepted.

To achieve cleanup faster and to expedite the DERR's review of the data submitted, the Owner/Operator completes the Tier 2 Risk Assessment worksheets in Appendix A and provides as many site-specific details as possible. Attach additional sheets if necessary.

Appendix B must contain copies of original data such as site maps, boring logs, pump tests, modeling input and output and other data as determined necessary by the Executive Secretary (UST) to support site-specific parameter values, final SSCLs, and ALs, if applicable.

Attach solutions (input and output) to the exposure equations for calculating cleanup levels to Appendix C. Always show the intermediate steps when performing electronic or manual calculations.

Worksheet #1 is the Risk Assessment report where elements of the Cleanup Standards Policy are discussed, and where site-specific details are provided about the facility including the nature of the release, cleanup measures performed, an exposure summary, and contaminant fate and transport data are provided and discussed. Worksheet #1 also contains the format for presenting the representative contaminant concentrations and the calculated cleanup levels.

Use Worksheet #2 to provide site-specific values for the parameters required for calculating SSCLs and ALs, if applicable.

Use Worksheet #3, the Site Conceptual Exposure Model (SCEM), to identify and discuss exposure pathways, impacted media, transport mechanisms, exposure media, complete exposure pathways, and required actions.

Worksheets #4a through 4e are provided for determining plume stability and contaminant mass balance.

All supporting data for the worksheets are to be attached to Appendix B. Use additional sheets as necessary for any of the sections in the worksheets.

WORKSHEET #1

RISK ASSESSMENT REPORT

- INSTRUCTIONS:**
1. Enclose an Executive Summary not to exceed 2 pages in length.
 2. Complete this Worksheet #1. Attach additional sheets as necessary.
 3. Discuss figures, maps, cross-sections, graphs, tables, calculations, and other supporting documentation in the Appendices as they relate to this report.

DERR Project Manager: _____
Completed by: _____

Date Completed: _____

A. Facility Identification: *Complete the following portion in full.*

Facility ID #: _____ Release ID: _____
Facility Name: _____
Facility Location and Address: _____
Facility Owner/Operator: _____

B. Person Completing the Tier 2 Risk Assessment: *Print and sign your name in this portion to acknowledge that you are providing accurate information used for formulating your conclusions regarding any remaining contamination, exposure pathways and receptors. If exposure pathways are complete, receptors are likely to be at risk, and further action may therefore be necessary.*

The information provided herein is accurate to the best of my knowledge and best professional judgment.

Print Name and Company

Sign Name

Date

Certified Consultant #

C. Facility History: *Summarize each of the following:* Type and number of years of facility operation; location, cause and nature of the release; type, quantity and age of the release; impacted media; contaminant source elimination and/or control measures; abatement and/or corrective action measures taken.

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

D. Site Characterization and Assessment: *Describe site characteristics and assessment results including the following:* Methods used to characterize the site and investigate the contamination; land use (on-site and off-site); topographic features including type of ground cover; soil type; geologic and hydrologic features as they relate to the site; location and type of receptors, property lines and utility lines; impacts to receptors; initial and final site classification (see Utah Department of Environmental Quality, DERR, 1997).

E. Nature and Extent of Contamination: Discuss the nature, extent and behavior of contamination in all impacted media, and past and present occurrence of free product using supporting documentation such as figures, maps, cross-sections, graphs, tables, plume stability evaluations, calculations, attenuation mechanisms, and other data. Discuss the type and dimensions of impacted media, and investigative and confirmation sampling results.

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

F. Tier 2 Options: Calculating Site-Specific Cleanup Levels (SSCLs): *Mark the applicable spaces provided below, ☐, for the option used to calculate and/or derive SSCLs, and describe why the Option was used.*

☐ OPTION 1: ☐ On-site impacts only.

Are the SSCLs for applicable exposure pathways exceeded?

Yes ☐: Cleanup is reasonable. Submit a Risk Assessment report and Corrective Action Plan in conformance with Step 2.22 of the Tier 2 Step-by-Step Procedures and Documentation.

No ☐: Submit Risk Assessment report in conformance with Step 2.23 of the Tier 2 Step-by-Step Procedures and Documentation.

☐ OPTION 2: ☐ On-site impacts ☐ Off-site impacts.

Describe and discuss the derivation and application of attenuation mechanisms:

☐ User-Supplied Natural Attenuation Factor ☐ Empirical Natural Attenuation Factor

☐ Electron Superposition

Are the SSCLs for applicable exposure pathways exceeded?

Yes ☐: Cleanup is reasonable. Submit a Risk Assessment report and Corrective Action Plan in conformance with Step 2.22 of the Tier 2 Step-by-Step Procedures and Documentation.

No ☐: Submit Risk Assessment report in conformance with Step 2.23 of the Tier 2 Step-by-Step Procedures and Documentation.

☐ OPTION 3: ☐ On-site impacts ☐ Off-site impacts

Describe and discuss the derivation and application of attenuation mechanisms:

☐ User-Supplied Natural Attenuation Factor ☐ Empirical Natural Attenuation Factor ☐ First-Order Decay

☐ Electron Superposition ☐ Other: _____

Are the SSCLs and ALs for applicable exposure pathways exceeded?

Yes ☐: Cleanup is reasonable. Submit a Risk Assessment report and Corrective Action Plan in conformance with Step 2.22 of the Tier 2 Step-by-Step Procedures and Documentation.

No ☐: Submit Risk Assessment report in conformance with Step 2.23 of the Tier 2 Step-by-Step Procedures and Documentation.

☐ OPTION 4: ☐ On-site impacts ☐ Off-site impacts

Describe and discuss the derivation and application of attenuation mechanisms:

☐ User-Supplied Natural Attenuation Factor ☐ Empirical Natural Attenuation Factor ☐ First-Order Decay

☐ Electron Superposition ☐ Other: _____

Are the SSCLs and ALs for applicable exposure pathways exceeded?

Yes ☐: Cleanup is reasonable. Submit a Risk Assessment report and Corrective Action Plan in conformance with Step 2.22 of the Tier 2 Step-by-Step Procedures and Documentation.

No ☐: Submit Risk Assessment report in conformance with Step 2.23 of the Tier 2 Step-by-Step Procedures and Documentation.

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

G. Exposure Assessment:

The purpose of the exposure assessment is to estimate the type and magnitude of exposures to receptors by the COCs that are present at or migrating from the site.. The exposure assessment describes the current and anticipated land use, identifies current and potentially complete exposure pathways, and quantifies exposure to receptors.

Instructions

1. Check the boxes below where applicable.
2. Discuss each current and potentially complete exposure pathway, on-site and off-site receptors, and land use and exposed populations in the space provided. Exposure pathways are complete in accordance with Worksheet #3 (Site Conceptual Exposure Model), and when all the following conditions exist: (a) Receptors are present; (b) Transport mechanisms are active, and; (c) The SSCLs or ALs are exceeded. A potentially complete exposure pathway is one that is likely to be complete in the future, generally within 5 to 10 years.
3. If pathways are potentially complete, discuss the likelihood of receptors being exposed to contaminant concentrations greater than the TER (i.e., a 10^{-6} TER for carcinogenic compounds, 1.0 Hazard Quotient for non-carcinogenic compounds, MCLs or other standards).

AIR EXPOSURE PATHWAY

Surface soils, vapor inhalation and dust ingestion: ☐ Currently complete ☐ Potentially complete

[NOTE: The Surface Soil pathway must be considered if subsurface soil will potentially be excavated.]

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Subsurface soil, vapor intrusion to outdoor air: ☐ Currently complete ☐ Potentially complete

NOTE: Subsurface soil has the potential to become surface soil if it is excavated.

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Facility ID #: _____
Facility Name & Location: _____

Date Completed: _____
Completed by: _____
DERR Project Manager: _____

G. Exposure Assessment, *continued*

AIR EXPOSURE PATHWAY, *continued*

Subsurface soil, vapor intrusion to indoor air: ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Groundwater, vapor intrusion to outdoor air: ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Facility ID #: _____
Facility Name & Location: _____

Date Completed: _____
Completed by: _____
DERR Project Manager: _____

G. Exposure Assessment, *continued*

AIR EXPOSURE PATHWAY, *continued*

Groundwater, vapor intrusion to indoor air: ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

GROUNDWATER EXPOSURE PATHWAY

Soil leaching to groundwater (for ingestion): ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Facility ID #: _____
Facility Name & Location: _____

Date Completed: _____
Completed by: _____
DERR Project Manager: _____

G. Exposure Assessment, *continued*

GROUNDWATER EXPOSURE PATHWAY, *continued*

Groundwater ingestion: ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

SOIL EXPOSURE PATHWAY *[NOTE: This pathway must be considered if subsurface soil will potentially be excavated.]*

Surface soil, dermal contact or ingestion: ☐ Currently complete ☐ Potentially complete
Construction Worker: ☐ Currently complete ☐ Potentially complete

Discuss pathway and on-site and off-site receptors that are or may be at risk of exposure to greater than the TER, MCLs or other applicable standards:

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

G. Exposure Assessment, *continued*

Utility Lines:

☐ **Currently impacted**

☐ **Potentially impacted**

Discuss current and potential impacts to utility lines. Describe and discuss conditions where contamination currently or potentially intersects the contamination, and make recommendations for protecting utility lines:

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

H. Contaminant Transport, Fate, Attenuation and Exposure Summary: *Contaminants must attenuate to the Target Excess Risk level (10^{-6} and Hazard Quotient = 1.0), MCLs or other applicable standards at all receptors.*

INSTRUCTIONS FOR OPTION 3 and OPTION 4

Introduction

Transient analytical modeling is required for Option 3, and transient analytical and numerical modeling are required for Option 4.

A model is a simplified version of actual field conditions that allows the knowledge of a site to be quantified. Effective and accurate modeling requires abundant site data and possibly regional data. Models may vary in their sensitivity to certain parameters. For example, SOLUTE is sensitive to groundwater velocity, retardation factor, and half-life due to COC decay (not advection). The BIOSCREEN model is sensitive to the source term. The BIOPLUME model is a complex model that requires dissolved oxygen data, and possibly data that describe heterogenous conditions.

It is good modeling practice to perform and evaluate numerous model runs to accurately assess site conditions, and to determine the sensitivity of various parameters. Some input parameters that may be needed are identified in Worksheet #2.

Transient contaminant fate and transport computer modeling may be necessary for estimating the likelihood of a contaminant plume (adsorbed, dissolved and vapor phases) to persist in a way that threatens human or environmental health. Models can assist in determining if exposure pathways are currently and potentially complete, if site-specific cleanup levels are currently or potential exceeded for each exposure pathway, and the estimated duration of the contamination.

Instructions

Complete each section provided below to convey the reasons for modeling, the results and accuracy of the modeling compared to the actual site conditions, and the modeling results as tools to indicate potential exposure to receptors. Use additional sheets as necessary. Attach input, output, and other data files and graphics to Appendix C.

1. Fate and Transport Models Used (*check the applicable below and specify analytical or numerical*)

- a. ☐ Solute transport: Names and Governing Equations:
- b. ☐ Leaching from Vadose Zone: Names and Governing Equations:
- c. ☐ Leaching from Vadose Zone, Volatilization and Vapor Transport, Adsorbed Remaining: Names and Governing Equations:
- d. ☐ Other models: Names and Governing Equations:

2. Purpose and Objectives of Modeling: Discuss the purpose and objectives for modeling as they relate to the following: (a) Understanding the nature and extent of the contamination; (b) Evaluating currently or potentially complete exposure pathways and exposure to receptors; (c) Discuss how modeling results show the allowable SSCL values in space and time, and the time required to achieve the TER at each relevant point of exposure, and; (d) Discuss the duration, location and fate of the COCs for the complete exposure pathways if the applicable SSCLs at the POC, ALs at AMPs, or RBSLs, MCLs or other applicable standards at POEs are exceeded.

Facility ID #: _____ Date Completed: _____
Facility Name & Location: _____ Completed by: _____
_____ DERR Project Manager: _____

H. Contaminant Transport, Fate, Attenuation and Exposure Summary, *continued*

3. Discuss transient parameters used in the modeling, including time simulation periods and time steps, and their comparison to site data:

4. Discuss the input parameters for each model used and their comparison to site data. Input parameters must accurately reflect site conditions and correspond to Worksheet #2 and Worksheet #4, if applicable.

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

H. Contaminant Transport, Fate, Attenuation and Exposure Summary, *continued*

5. Discuss the results of the sensitivity analysis and model calibration efforts:

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

I. Public Notification:

Public notification is required prior to case file closure. Public notification must reach the segment of the public (on-site and off-site) who may be directly or potentially affected by the contaminated media. Public notification may be accomplished by personal contact or notice, notice in newspapers or distribution of flyers.

NOTE: DO NOT PROCEED WITH PUBLIC NOTIFICATION UNTIL THE FORM SHOWN BELOW HAS BEEN COMPLETED, AND REVIEWED AND APPROVED BY THE EXECUTIVE SECRETARY (UST).

Instructions: Complete the Public notification form below and use it as the public notification.

1. Name and address of the release site:

2. Provide a brief summary of the release and the site conditions:

3. Results of the Tier 2 Risk Assessment:

4. Name, agency address and telephone number of the DERR project manager:

5. Location, dates and time where the Tier 2 Risk Assessment can be viewed by the public:

6. Describe how the public will be notified:

Facility ID #: _____

Facility Name & Location: _____

Date Completed: _____

Completed by: _____

DERR Project Manager: _____

J. Conclusions and Recommendations: Discuss the extent and degree of contamination, plume stability, concentrations of COCs, required SSCLs and ALs, if applicable, complete exposure pathways, exposure to receptors and impact and potential impact to human health and the environment, economic considerations and cost-effectiveness of cleanup options, technologies available for use in cleanup, and future work needed to protect receptors and POEs to the TER, MCLs or other applicable standards.

Facility ID #: _____

Date Completed: _____

Facility Name & Location: _____

Completed by: _____

DERR Project Manager: _____

K. Risk Management Decisions and Uncertainties: Discuss risk management issues and uncertainties. Figures 2-4 and A-1, and Table A-5 are provided to assist with identifying and addressing these issues; these figures and tables are not to be included in this report.

L. Technical References Cited for Users: List references , if applicable, that were used for this report.

M. DERR RECOMMENDATIONS, FOR DERR USE ONLY

- ☐ No further action
- ☐ No further action with environmental controls, as follows:
- ☐ Monitoring:
- ☐ Further cleanup necessary:
- ☐ Other, explain:

DERR Project Manager
(Print Name)

DERR Project Manager
(Sign Name)

Date

Table A-1: Site-Specific Cleanup Levels for Surface Soil
(less than 3 feet below land surface)

INSTRUCTIONS:

1. ☐ Check this box if you are manually calculating SSCLs. You must then complete this form in full. See Appendix C, Table C-1 to manually calculate.
2. ☐ Check this box if you are electronically calculating SSCLs. You must include a completed form similar to the one shown below.
3. Complete the information requested in the spaces provided.
4. Check the boxes (☐) that apply to the site and enter actual and calculated contaminant concentrations.

Site Name: _____			Completed By (print your name): _____							
Site Location and Address: _____			Company or Agency Name: _____							
_____, Utah			Date Completed: _____							
Facility ID #: _____ Release ID: _____			Certified Consultant #: _____							
			Target Excess Risk (Class A & B): 10 ⁻⁶ required Target Excess Risk (Class C): 10 ⁻⁶ required Hazard Quotient: 1.0 required		Calculation Option (check one): <input type="checkbox"/> OPTION 1 <input type="checkbox"/> OPTION 2 <input type="checkbox"/> OPTION 3 <input type="checkbox"/> OPTION 4					
CONSTITUENTS OF CONCERN			SSCL Results For Complete Exposure Pathways <i>(Check boxes below for the applicable condition).</i>							Applicable SSCL Exceeded?
			Soil Leaching to Groundwater (groundwater for ingestion) <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete			Ingestion, Inhalation and Dermal Contact <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		Construction Worker <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		
CAS No.	Name in alphabetical order	Enter below the Representative Source Area Concentrations (mg/kg)	Residential <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	MCLs or other applicable standards	Residential: <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Applicable SSCL (mg/kg) (Enter the lowest SSCL for any complete exposure pathway)	
71-43-2	Benzene									□
100-41-4	Ethylbenzene									□
1634-04-4	Methyl t-Butyl Ether									□
91-20-3	Naphthalene									□
108-88-3	Toluene									□
1330-20-7	Xylenes (mixed isomers)									□
	Others (list here):									

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**Table A-2: Site-Specific Cleanup Levels for Subsurface Soil
(greater than 3 feet below land surface)**

- INSTRUCTIONS:**
- ☐ Check this box if you are manually calculating SSCLs. You must then complete this form in full. See Appendix C, Table C-1 to manually calculate.
 - ☐ Check this box if you are electronically calculating SSCLs. You must include a completed form similar to the one shown below.
 - Complete the information requested in the spaces provided.
 - Check the boxes (☐) that apply to the site and enter actual and calculated contaminant concentrations.

Site Name: _____			Completed By (print your name): _____							
Site Location and Address: _____, Utah			Company or Agency Name: _____							
Facility ID #: _____ Release ID: _____			Date Completed: _____							
			Certified Consultant #: _____							
			Target Excess Risk (Class A & B): 10 ⁻⁶ required Target Excess Risk (Class C): 10 ⁻⁶ required Hazard Quotient: 1.0 required		Calculation Option (check one): <input type="checkbox"/> OPTION 1 <input type="checkbox"/> OPTION 2 <input type="checkbox"/> OPTION 3 <input type="checkbox"/> OPTION 4					
CONSTITUENTS OF CONCERN			SSCL Results For Complete Exposure Pathways <i>(Check boxes below for the applicable condition).</i>							Applicable SSCL Exceeded?
			Soil Leaching to Groundwater (groundwater for ingestion)			Soil Volatilization to Indoor Air		Soil Volatilization to Outdoor Air		
			<input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete			<input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		<input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		
CAS No.	Name	Enter below the Representative Source Area Concentrations (mg/kg)	Residential <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	MCLs or other applicable standards	Residential: <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Applicable SSCL (mg/kg) (Enter the lowest SSCL for any complete exposure pathway)	check (✓) If yes
71-43-2	Benzene									<input type="checkbox"/>
100-41-4	Ethylbenzene									<input type="checkbox"/>
1634-04-4	Methyl t-Butyl Ether									<input type="checkbox"/>
91-20-3	Naphthalene									<input type="checkbox"/>
108-88-3	Toluene									<input type="checkbox"/>
1330-20-7	Xylenes (mixed isomers)									<input type="checkbox"/>
	Others (list here):									

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Table A-3: Site-Specific Cleanup Levels for Groundwater

INSTRUCTIONS:

1. ☐ Check this box if you are manually calculating SSCLs or ALs. You must then complete this form in full. See Appendix C, Table C-1 to manually calculate.
2. ☐ Check this box if you are electronically calculating SSCLs or ALs. You must include a completed form similar to the one shown below.
3. Complete the information requested in the spaces provided.
4. Check the boxes (☐) that apply to the site and enter actual and calculated contaminant concentrations.

Site Name: _____			Completed By (print your name): _____							
Site Location and Address: _____, Utah			Company or Agency Name: _____							
Facility ID #: _____ Release ID: _____			Date Completed: _____							
			Certified Consultant #: _____							
			<input type="checkbox"/> Calculation for SSCLs <input type="checkbox"/> Calculation for ALs, if applicable.							
			Locations and Names of AMPs: _____							
			Target Excess Risk (Class A & B): 10 ⁻⁶ required Target Excess Risk (Class C): 10 ⁻⁶ required Hazard Quotient: 1.0 required		Calculation Option (check one): <input type="checkbox"/> OPTION 1 <input type="checkbox"/> OPTION 2 <input type="checkbox"/> OPTION 3 <input type="checkbox"/> OPTION 4					
CONSTITUENTS OF CONCERN			SSCL Results For Complete Exposure Pathways <i>(Check boxes below for the applicable condition and enter SSCL in applicable locations).</i>							Applicable SSCL Exceeded?
			Groundwater Ingestion <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete			Groundwater Volatilization to Indoor Air <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		Groundwater Volatilization to Outdoor Air <input type="checkbox"/> Currently Complete <input type="checkbox"/> Potentially Complete		
CAS No.	Name	Enter below the Representative Source Area Concentrations (mg/kg)	Residential <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	MCLs or other applicable standards	Residential: <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Commercial <input type="checkbox"/> on-site <input type="checkbox"/> off-site	Applicable SSCL (mg/kg) (Enter the lowest SSCL for any complete exposure pathway)	check (✓) if yes
71-43-2	Benzene									<input type="checkbox"/>
100-41-4	Ethylbenzene									<input type="checkbox"/>
1634-04-4	Methyl t-Butyl Ether									<input type="checkbox"/>
91-20-3	Naphthalene									<input type="checkbox"/>
108-88-3	Toluene									<input type="checkbox"/>
1330-20-7	Xylenes (mixed isomers)									<input type="checkbox"/>
	Others (list here):									

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Table A-4: Example of Action Levels for Alternate Monitoring Points for the Groundwater Pathway*

			Distance from Source Area to Three Alternate Monitoring Points (AMP) and Corresponding Action Levels for Constituents			Distance to Receptor and Contaminant Concentration Required at the Receptor (mg/L)
CAS No.	Constituent	SSCLs (mg/L) for the Source Area	AMP #1 10 (feet)	AMP #2 50 (feet)	AMP #3 100 (feet)	Receptor 200 (feet)
71-43-2	Benzene	4.6E-3	4.6E-3	4.6E-3	4.3E-3	2.9E-3
100-41-4	Ethylbenzene	5.8E+0	5.8E+0	5.8E+0	5.3E+0	3.7E+0
1634-04-4	Methyl t-Butyl Ether	2.9E-1	2.9E-1	2.9E-1	2.7E-1	1.8E-1
91-20-3	Naphthalene	2.3E-1	2.3E-1	2.3E-1	2.1E-1	1.5E-1
108-88-3	Toluene	1.2E+1	1.2E+1	1.2E+1	1.1E+1	7.3E+0
1330-20-7	Xylene (mixed isomers)	1.2E+2	1.2E+2	1.2E+2	1.1E+2	7.3E+1

* This table is an example only of an Option 3 or Option 4 case for a receptor located 200 feet down-gradient of a source area, and three AMPs located along plume centerline between the source area and the receptor.

WORKSHEET #2

DATA REQUIREMENTS

Instructions

Worksheet #2 identifies the data requirements for Option 1 through Option 4. Use Worksheet #2 to determine the general data requirements, the site-specific parameters that must be evaluated, and the required exposure and cross-media transport parameters that are used to calculate and/or derive Tier 2 SSCLs and ALs, if applicable, for the appropriate Option.

Non-site-specific parameter values that are required by the DERR are shown in Appendix C, Tables C-2 and C-3. These include, for example, target excess risk (TER) limit, exposure duration, ingestion rates, inhalation rates, volume of enclosed spaces, chemical property and toxicity values, and other assumptions.

Worksheet #2 must be completed in full by marking the applicable spaces provided. Copies of the raw original data used for developing the site-specific parameter values must be provided in Appendix B.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4
INSTRUCTIONS: mark the boxes provided, ☐ , to ensure that each condition below is met

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	
<p align="center">Subsurface Investigation and Monitoring Requirements</p> <p><i>NOTE: The number of sampling and monitoring locations, the number of years for monitoring, and the COCs to be analyzed are recommended and subject to change as determined by the Executive Secretary (UST). These parameters must be capable of defining the extent and degree of contamination, the plume centerline, if applicable, and the nature of the contaminant plume.</i></p>	<input type="checkbox"/> Extent (horizontal and vertical) and degree of soil and groundwater (if applicable) contamination must be defined. <input type="checkbox"/> Subsurface Investigation requirements in accordance with Appendix D.				
	<input type="checkbox"/> 4 sampling locations or other as needed of impacted media to define the extent and degree of contamination and plume centerline.	<input type="checkbox"/> 6 sampling locations or other as needed of impacted media to define the extent and degree of contamination and plume centerline.	<input type="checkbox"/> Plumes < 10,000 ft² : 7 sampling locations of impacted media, and at 5-foot vertical intervals for soil analysis and logging. <input type="checkbox"/> Plumes > 10,000 ft² : 7 sampling locations plus 1 location every additional 100 horizontal feet of impacted media, and samples collected at 5-foot vertical intervals for soil analysis and logging within contaminant area.	<input type="checkbox"/> Plumes < 10,000 ft² : 12 sampling locations of impacted media, and at 5-foot vertical intervals for soil analysis and logging. <input type="checkbox"/> Plumes > 10,000 ft² : 12 sampling locations plus 1 location every additional 100 horizontal feet of impacted media, and samples collected at 5-foot vertical intervals for soil analysis and logging within contaminant area.	
	<input type="checkbox"/> Tabulated analytical data for: Gasoline: BTEXN, MTBE, TPH (methods 8020B/8015B modified); Diesel: BTEXN, TPH (methods 8020B/8015 modified); Waste Oil: BTEXN, MTBE, TRPH or Oil & Grease, Solvents; New Oil: TRPH or Oil & Grease (See Appendix E-1 for complete sampling guide). <input type="checkbox"/> TPH fractionation ^a : Analyze at least 1 representative sample from the most contaminated area, of each contaminated medium, for TPH fractions using EPA methods 8260B/8270B. <input type="checkbox"/> Tabulated depth to groundwater and groundwater elevation, if applicable. <input type="checkbox"/> Site maps showing all sample locations, on-site buildings, property lines, utility lines, road ways, and other applicable on-site and off-site receptors. <input type="checkbox"/> Complete Appendix A Worksheets #1, #2 and #3, and Worksheet #4a through #4e if determination of plume stability and mass balance is necessary.				
	OPTIONAL to perform monitoring. If performed, mark the spaces provided where applicable:	<input type="checkbox"/> Minimum 1 year of quarterly monitoring, unless otherwise directed by the DERR.	<input type="checkbox"/> Minimum 2 years of quarterly monitoring, unless otherwise directed by the DERR.	<input type="checkbox"/> Minimum 5 years of quarterly monitoring, unless otherwise directed by the DERR.	
	Monitoring Constituents and Locations: <input type="checkbox"/> Constituents shown above (based on product type), depth to groundwater, groundwater elevation and hydraulic gradient. These help to determine plume stability. <input type="checkbox"/> Monitoring locations define extent, degree, and centerline of the contaminant plume.				
	OPTIONAL to monitor natural attenuation parameters: If performed, indicate below and circle the parameters monitored: <input type="checkbox"/> For groundwater monitoring, measure Dissolved Oxygen and sample Dissolved/Ferrous Iron (Fe ²⁺), Nitrate, Sulfate, Oxidation/Reduction Potential or other (AFCEE, 1996) ^b in addition to BTEXN, MTBE, TPH.		Monitor natural attenuation parameters shown below: Indicate below and circle the parameters monitored: <input type="checkbox"/> For groundwater monitoring, measure Dissolved Oxygen and sample Dissolved/Ferrous Iron (Fe ²⁺), Nitrate, Sulfate, Oxidation/Reduction Potential, or other (AFCEE, 1996) ^b in addition to BTEXN, MTBE, TPH.		
<input type="checkbox"/> OPTIONAL to perform vapor monitoring for Oxygen, Carbon Dioxide, and BTEXN, MTBE, TPH.	<input type="checkbox"/> If applicable , perform vapor monitoring for Oxygen, Carbon Dioxide, and BTEXN, MTBE, TPH.				

^a See Section 2 (Constituents of Concern) for details concerning TPH fractionation.
^b Note that the sampling efforts are valid only for those electron acceptors that show a positive correlation to contaminant plumes.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, continued
INSTRUCTIONS: mark the boxes provided, ☐ , to ensure that each condition below is met

	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Plume Stability <i>Use Worksheets #4a through #4e to document plume stability and mass balance.</i>	PLUME MUST BE STABLE OR DIMINISHING <i>(Note: plume stability may not be possible without monitoring data)</i> Plume is: <input type="checkbox"/> Stable <input type="checkbox"/> Diminishing <input type="checkbox"/> Expanding <i>☛ If plume is not stable or diminishing, go to next applicable Option, or submit Risk Assessment report and CAP.</i>	PLUME MUST BE STABLE OR DIMINISHING Plume is: <input type="checkbox"/> Stable <input type="checkbox"/> Diminishing <input type="checkbox"/> Expanding <i>☛ If plume is not stable or diminishing, go to next applicable Option, or submit Risk Assessment report and CAP.</i>	PLUME MAY BE STABLE, DIMINISHING OR EXPANDING Plume is: <input type="checkbox"/> Stable <input type="checkbox"/> Diminishing <input type="checkbox"/> Expanding <i>☛ If plume is not stable or diminishing, Option 4 may be required, or submit Risk Assessment report and CAP.</i>	PLUME MAY BE STABLE, DIMINISHING OR EXPANDING Plume is: <input type="checkbox"/> Stable <input type="checkbox"/> Diminishing <input type="checkbox"/> Expanding <i>☛ If plume is not stable or diminishing, submit Risk Assessment report and CAP.</i>
NAF Calculation Requirements	not applicable	Minimum of 3 sampling points located along the plume centerline	Minimum of 4 sampling points located along the plume centerline	Minimum of 6 sampling points located along the plume centerline
Modeling Requirements	<input type="checkbox"/> Steady state: Solve equations shown in Appendix C Table C-1.	<input type="checkbox"/> Steady state: Solve equations shown in Appendix C Table C-1.	<input type="checkbox"/> Steady state: Solve equations shown in Appendix C Table C-1. <input type="checkbox"/> For dissolved phases, if preliminary SSCLs are exceeded, or if plume is expanding, transient analytical modeling is required to determine when SSCLs and ALs will be met. <input type="checkbox"/> For adsorbed phases, transient analytical or numerical.	<input type="checkbox"/> Steady state: Solve equations shown in Appendix C Table C-1. <input type="checkbox"/> For dissolved phases, if preliminary SSCLs are exceeded, or if plume is expanding transient analytical and transient numerical modeling required to determine when SSCLs and ALs will be met. <input type="checkbox"/> For adsorbed phases, transient analytical or numerical.
Appendices	<input type="checkbox"/> Appendix A: <input type="checkbox"/> Worksheet #1: Risk Assessment Report <input type="checkbox"/> Worksheet #2: Data Requirements for Options 1 through 4 <input type="checkbox"/> Worksheet #3: Site Conceptual Exposure Model <input type="checkbox"/> Worksheets #4a through #4e: Plume Stability Worksheets <input type="checkbox"/> Appendix B: Site-Specific Data Requirements and Attachments (maps, cross-sections, graphs, data tables, other) <input type="checkbox"/> Appendix C: Calculations for Site-Specific Cleanup Levels (manual or electronic) <input type="checkbox"/> Appendix D: Subsurface Investigation Report. Applicable portions of this report may be attached to the Risk Assessment report. <input type="checkbox"/> Appendix E: Corrective Action Plan (<i>may precede the Tier 2 Risk Assessment; applicable portions of this report may be attached to the Risk Assessment Report</i>).			

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Distance to Receptors and Other Features

INSTRUCTIONS: Enter the distances and directions from the source and/or AMPs to each receptor and other features for the applicable option below. For example, if you are conducting an Option 2 Risk Assessment, enter the distances from the source to each receptor and other features in the Option 2 column. Include only those features that are applicable. All features must be indicated and easily correlated with the maps and cross-sections shown in Appendix B.

Receptors and Other Features	Option 1	Option 2	Option 3	Option 4
Subsurface Utility Lines: <div style="margin-left: 150px;">Water</div> <div style="margin-left: 150px;">Sewer</div> <div style="margin-left: 100px;">Storm Drain</div> <div style="margin-left: 100px;">Natural Gas</div> <div style="margin-left: 100px;">Telephone</div> <div style="margin-left: 100px;">Electrical</div> <div style="margin-left: 50px;">Other, specify: _____</div>	<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>	<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>	<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>	<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>
Municipal Water Wells				
Domestic Water Wells				
Irrigation Water Wells				
Other Water Wells				
Surface Water Bodies				
Property Lines				
Residential Buildings				
Commercial Buildings				

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, <input checked="" type="checkbox"/>, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements																									
				OPTION 1	OPTION 2																								
				<i>Mark the spaces provided or enter values, <input checked="" type="checkbox"/>, where applicable</i> <i>For Field-Measured parameters, use average and representative values.</i>																									
A	Contaminated Soil Area (ft ²)	site-specific measurement		Minimum 3 locations. Enter # locations: ___ Drilling ___ Driving ^a ___ Digging	Minimum 4 locations. Enter # locations: ___ Drilling ___ Driving ^a ___ Digging																								
AT _c	Averaging Time for carcinogens, years	Residential/ <u>Unknown</u> 70 Commercial/ <u>Industrial</u> 70 Construc- <u>tion</u> 70		Values provided are not variable																									
AT _{nc}	Averaging Time for non-carcinogens, years	Residential/ <u>Unknown</u> 30 Commercial/ <u>Industrial</u> 25 Construc- <u>tion</u> 1		Values provided are not variable																									
BC _i	Biodegradation Capacity available for constituent <i>i</i> unitless	Show values at right if calculated		calculated, see Table C-1, equation C.23																									
BC _T	Biodegradation Capacity for all electron acceptors in groundwater unitless	Show value at near right if calculated (to calculate, see Table C-1, equation C.23). Enter electron acceptor data at far right.		Enter Electron Acceptor Concentrations Below (mg/L) <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th><th style="text-align: center;"><u>Inside Plume</u></th><th style="text-align: center;"><u>Background</u></th><th style="text-align: center;"><u>Δ</u></th></tr> </thead> <tbody> <tr> <td>Dissolved Oxygen*</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td></tr> <tr> <td>Dissolved Sulfate*</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td></tr> <tr> <td>Dissolved Nitrate*</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td></tr> <tr> <td>Dissolved Iron (observed within the plume)**</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td></tr> <tr> <td>Methane (observed within the plume)**</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td><td style="text-align: center;">_____</td></tr> </tbody> </table> <p>Note: Δ = concentration inside the plume minus background concentration. * = use Δ values of these parameters to calculate BC. ** = use inside-plume values to calculate BC.</p>			<u>Inside Plume</u>	<u>Background</u>	<u>Δ</u>	Dissolved Oxygen*	_____	_____	_____	Dissolved Sulfate*	_____	_____	_____	Dissolved Nitrate*	_____	_____	_____	Dissolved Iron (observed within the plume)**	_____	_____	_____	Methane (observed within the plume)**	_____	_____	_____
	<u>Inside Plume</u>	<u>Background</u>	<u>Δ</u>																										
Dissolved Oxygen*	_____	_____	_____																										
Dissolved Sulfate*	_____	_____	_____																										
Dissolved Nitrate*	_____	_____	_____																										
Dissolved Iron (observed within the plume)**	_____	_____	_____																										
Methane (observed within the plume)**	_____	_____	_____																										
BW	Body weight, adults, kg	Residential/ <u>Unknown</u> 70 Commercial/ <u>Industrial</u> 70 Construc- <u>tion</u> 70		Values provided are not variable																									

Notes: - indicates that condition does not apply; ^a driving refers to direct-push sampling techniques

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
$C(ea)_n$	Concentration of electron acceptor n in groundwater, mg/L	Tabulate data in Appendix B		field measured	
d	Thickness of surficial soil, ft	Residential/ <u>Unknown</u> 3.28 Commercial/ <u>Industrial</u> 3.28 Construc- <u>tion</u> 3.28		Values provided are not variable	
D^{air}	Diffusiion coefficient in air, cm^2/sec	chemical-and fraction-specific		see Appendix C Table C-2	
D_s^{eff}	Effective diffusivity in vadose zone soils, cm^2/sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	
d_s	Thickness of contaminated subsurface soil (feet)	site-specific measurement	d_s : _____ Depth to top: _____ Depth to base: _____	Minimum 3 locations. Enter # locations: ____ Drilling ____ Driving ____ Digging	Minimum 4 locations. Enter # locations: ____ Drilling ____ Driving ____ Digging
D_{crack}^{eff}	Effective diffusivity through foundation cracks, cm^2/sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
D_{capf}^{eff}	Effective diffusivity in capillary fringe zone cm ² /sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	
D_{ws}^{eff}	Effective diffusivity above the water table, cm ² /sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	
D^{wat}	Diffusiion coefficient in water, cm ² /sec	chemical-and fraction-specific		see Appendix C Table C-2	
ED	Exposure duration, adults years	<u>Residential/</u> <u>Unknown</u> 30 <u>Commercial/</u> <u>Industrial</u> 25 <u>Construc-</u> <u>tion</u> 1		Values shown are not variable	
EF	Exposure frequency, adults days/year	<u>Residential/</u> <u>Unknown</u> 350 <u>Commercial/</u> <u>Industrial</u> 250 <u>Construc-</u> <u>tion</u> 250		Values shown are not variable	
ER	Enclosed space air exchange rate 1/sec = sec ⁻¹	<u>Residential/</u> <u>Unknown</u> 0.00014 sec ⁻¹ <u>Commercial/</u> <u>Industrial</u> 0.00023 sec ⁻¹ <u>Construc-</u> <u>tion</u> -		Values shown are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
foc, saturated	Fraction of organic carbon content, saturated zone ³	<input type="checkbox"/> Clay 0.28% <input type="checkbox"/> Silty clay 0.25% <input type="checkbox"/> Silt 0.25% <input type="checkbox"/> Clayey silt 0.25% <input type="checkbox"/> Silty sand 0.05% <input type="checkbox"/> Clayey sand (fine sand) 0.05% <input type="checkbox"/> Clean sand (medium sand) 0.05% <input type="checkbox"/> Gravel (coarse sand) 0.05%		To determine soil type, collect a minimum of 3 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, collect a minimum of 4 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
foc, unsaturated	Fraction of organic carbon content, unsaturated zone ^{1,9}	<input type="checkbox"/> Clay 0.55% <input type="checkbox"/> Silty clay 0.50% <input type="checkbox"/> Silt 0.50% <input type="checkbox"/> Clayey silt 0.50% <input type="checkbox"/> Silty sand 0.10% <input type="checkbox"/> Clayey sand (fine sand) 0.10% <input type="checkbox"/> Clean sand (medium sand) 0.10% <input type="checkbox"/> Gravel (coarse sand) 0.10%		To determine soil type, collect a minimum of 3 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, collect a minimum of 4 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values): Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements																			
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2																		
H	Henry's Law Constant (dimensionless, L-H ₂ O/L-air)	chemical-and fraction-specific see Appendix C Table C-2		Values are not variable																			
h_{capf}	Thickness of capillary fringe (feet) ^{1, 2} $L_{GW} - h_v = h_{capf}$	<table border="0"> <tr> <td>Saturated Medium</td><td>Capillary Fringe Thickness (feet)</td></tr> <tr> <td><input type="checkbox"/> Clay</td><td>5</td></tr> <tr> <td><input type="checkbox"/> Silty clay</td><td>4</td></tr> <tr> <td><input type="checkbox"/> Silt</td><td>3</td></tr> <tr> <td><input type="checkbox"/> Clayey silt</td><td>4</td></tr> <tr> <td><input type="checkbox"/> Silty sand</td><td>2</td></tr> <tr> <td><input type="checkbox"/> Clayey sand (fine sand)</td><td>1.5</td></tr> <tr> <td><input type="checkbox"/> Clean sand (medium sand)</td><td>0.8</td></tr> <tr> <td><input type="checkbox"/> Gravel (coarse sand)</td><td>0.25</td></tr> </table>	Saturated Medium	Capillary Fringe Thickness (feet)	<input type="checkbox"/> Clay	5	<input type="checkbox"/> Silty clay	4	<input type="checkbox"/> Silt	3	<input type="checkbox"/> Clayey silt	4	<input type="checkbox"/> Silty sand	2	<input type="checkbox"/> Clayey sand (fine sand)	1.5	<input type="checkbox"/> Clean sand (medium sand)	0.8	<input type="checkbox"/> Gravel (coarse sand)	0.25		To determine soil type, collect a minimum of 3 soil samples from top of saturated zone (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <i>Field measurements are not permissible.</i>	To determine soil type, collect a minimum of 4 soil samples from top of saturated zone (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <i>Field measurements are not permissible.</i>
Saturated Medium	Capillary Fringe Thickness (feet)																						
<input type="checkbox"/> Clay	5																						
<input type="checkbox"/> Silty clay	4																						
<input type="checkbox"/> Silt	3																						
<input type="checkbox"/> Clayey silt	4																						
<input type="checkbox"/> Silty sand	2																						
<input type="checkbox"/> Clayey sand (fine sand)	1.5																						
<input type="checkbox"/> Clean sand (medium sand)	0.8																						
<input type="checkbox"/> Gravel (coarse sand)	0.25																						
h_v	Thickness of vadose zone (feet)	site-specific measurement		Minimum 3 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging																		

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
I	Infiltration rate (feet/year) ⁷	<input type="checkbox"/> Clayey soils, unpaved site: I = (5%) X Annual Precipitation <input type="checkbox"/> Sandy soils, unpaved site: I = (10%) X Annual Precipitation <input type="checkbox"/> Paved site: I = (0.55%) X Annual Precipitation	Enter annual precip. in inches/year here: _____ Enter I here: _____	To determine soil or ground cover type, collect a minimum of 5 samples. It is permissible to use the formulas shown in column 3 provided there are no leaky utility lines or other sources of artificial recharge.	To determine soil or ground cover type, collect a minimum of 5 samples. It is permissible to use the formulas shown in column 3 provided there are no leaky utility lines or other sources of artificial recharge.
i	Hydraulic gradient (ft/ft)	Site-specific measurement.	Value _____ Range _____	If applicable, minimum of 1 round monitoring using 3 measurement points. _____ # Locations and rounds measured for <i>i</i>	Minimum of 1 year quarterly monitoring using a minimum of 3 measurement points. _____ # Locations and rounds measured for <i>i</i>
IR _{air-ind}	Inhalation rate, daily indoor, m ³ /day	Residential/ <u>Unknown</u> 20 Commercial/ <u>Industrial</u> 20 Construc- <u>tion</u> -		Values are not variable	
IR _{air-out}	Inhalation rate, daily outdoor, m ³ /day	Residential/ <u>Unknown</u> 20 Commercial/ <u>Industrial</u> 20 Construc- <u>tion</u> 10		Values are not variable	
IR _{soil}	Ingestion rate of soil, mg/day	Residential/ <u>Unknown</u> 114 Commercial/ <u>Industrial</u> 50 Construc- <u>tion</u> 100		Values are not variable	
IR _{water}	Ingestion rate, daily, liters/day	Residential/ <u>Unknown</u> 2 Commercial/ <u>Industrial</u> 1 Construc- <u>tion</u> -		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	<i>If applicable enter values used in unshaded cells</i>	<div style="text-align: center;">Data Requirements</div> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i> </div> <div style="width: 45%;"> OPTION 2 </div> </div>	
K	Hydraulic conductivity (feet/day) ^{4,5}	<div style="display: flex; justify-content: space-between;"> <div> <input type="checkbox"/> Clay <input type="checkbox"/> Silty clay <input type="checkbox"/> Silt <input type="checkbox"/> Clayey silt <input type="checkbox"/> Silty sand <input type="checkbox"/> Clayey sand (fine sand) <input type="checkbox"/> Clean sand (medium sand) <input type="checkbox"/> Gravel (coarse sand) </div> <div> 0.00283 0.07 1.42 0.0283 2.83 0.0283 28.3 283 </div> </div>	If measured, enter range of values: _____ _____ Enter average value: _____	<input type="checkbox"/> Value selected from permissible values. Sediment samples & stratigraphic profiles must be collected from a minimum of 3 locations within the upper 3 feet of the saturated zone. <input type="checkbox"/> Slug tests performed at 2 locations (<i>for shallow aquifers only. Use average and/or representative values</i>). _____ # Locations measured for each above, and identity of the locations.	<input type="checkbox"/> Value selected from permissible values. Sediment samples & stratigraphic profiles must be collected from a minimum of 4 locations within the upper 3 feet of the saturated zone. <input type="checkbox"/> Slug tests performed at 2 locations (<i>for shallow aquifers only. Use average and/or representative values</i>). _____ # Locations measured for each above, and identity of the locations.
Kd or k _s	Distribution coefficient, mL/g, L/kg	Show value for each constituent at right if calculating by hand		calculated: Kd = Koc X foc	
Koc	Adsorption coefficient, mL/g, L/kg	chemical-and fraction-specific see Appendix C Table C-2		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, <input checked="" type="checkbox"/>, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☞ Mark the spaces provided or enter values, <input checked="" type="checkbox"/>, where applicable</i> <i>☞ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
L_B	Enclosed space volume/ infiltration area ratio, cm	<u>Residential/</u> <u>Unknown</u> 200 <u>Commercial/</u> <u>Industrial</u> 300 <u>Construc-</u> <u>tion</u> -		Values are not variable	
L_{crack}	Foundation or wall thickness, cm	<u>Residential/</u> <u>Unknown</u> 15 <u>Commercial/</u> <u>Industrial</u> 15 <u>Construc-</u> <u>tion</u> -		Values are not variable	
L_{GW}	Depth to groundwater, ft $h_v + h_{capf} = L_{GW}$	site-specific measurement		Minimum 3 locations for each monitoring round. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations for each monitoring round. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
L_P	Length of Groundwater Contaminant Plume (feet)	site-specific measurement		Minimum 3 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
L_s	Depth to contaminated soil, ft	site-specific measurement	Top: ___ Base: ___	Minimum 3 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
M	Soil to skin adherence factor, mg/cm ²	<u>Residential/</u> <u>Unknown</u> 0.5 <u>Commercial/</u> <u>Industrial</u> 0.5 <u>Construc-</u> <u>tion</u> 0.5		Values are not variable	
P_e	Particulate emission rate, g/cm ² -sec	6.9 X 10 ⁻¹⁴		Value shown is not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
R	Retardation Factor, unitless	If calculated by hand, show values at right		calculated, see Appendix C, Table C-1, equation C.27	
RAF _d	Relative absorption factor, dermal, (volatiles/PAHs)	Residential/ <u>Unknown</u> 0.5/0.05 Commercial/ <u>Industrial</u> 0.5/0.05 Construc- <u>tion</u> 0.5/0.05		Values are not variable	
RAF _o	Relative absorption factor, oral, unitless	Residential/ <u>Unknown</u> 1.0 Commercial/ <u>Industrial</u> 1.0 Construc- <u>tion</u> 1.0		Values are not variable	
RBSL _i	Risk-based screening level for media “i” (mg/kg-soil; mg/L-water; or ug/m ³)			chemical-, media-, and exposure route-specific	
RfD _i	Reference Dose, inhalation, mg/kg-day	chemical-and fraction-specific; see Appendix C, Table C-2		Values are not variable	
RfD _o	Reference Dose, oral, mg/kg-day	chemical-and fraction-specific; see Appendix C, Table C-2		Values are not variable	
SA	Skin surface area cm ²	Residential/ <u>Unknown</u> 5800 Commercial/ <u>Industrial</u> 5800 Construc- <u>tion</u> 5800		Values are not variable	
SF _i	Cancer slope factor , inhalation (mg/kg-day) ⁻¹	chemical-specific; see Appendix C, Table C-2		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
SF _o	Cancer slope factor, oral (mg/kg-day) ⁻¹	chemical-specific; see Appendix C, Table C-2		Values are not variable	
TER	Target Excess Lifetime Cancer Risk, unitless	Residential/ <u>Unknown</u> 10 ⁻⁶ Commercial/ <u>Industrial</u> 10 ⁻⁶ Construc- <u>tion</u> 10 ⁻⁶		Values are not variable	
THQ	Target Hazard Quotient, unitless	Residential/ <u>Unknown</u> 1.0 Commercial/ <u>Industrial</u> 1.0 Construc- <u>tion</u> 1.0		Values are not variable	
U _{air}	Wind speed above ground surface in ambient mixing zone (cm/sec)	225		Value shown is not variable	
U _{darcy}	Groundwater Darcy velocity (feet/day)	site-specific measurement = Ki		Calculated only if criteria for i & K are met.	Calculated only if criteria for i & K are met.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
UF _n	Utilization Factor for electron acceptor <i>n</i> (i.e., mass ratio of electron acceptor to hydrocarbon consumed in biodegradation reactions; unitless).	Values shown at far right are for BTEX only and are not variable. Check cell at right if UFs are used.		Oxygen 3.14 Nitrate 4.90 Sulfate 4.6 Ferrous Iron 21.8 Methane 0.78	
U _{tran}	Groundwater Transport Velocity (feet/day)	site-specific measurement = Ki/θ _{eff}		Calculated only if criteria for i & K are met.	Calculated only if criteria for i & K are met.
VF _{samb}	Volatilization factor of subsurface soils to ambient air (mg/m ³ -air)/(mg/kg-soil)	Enter values at right		calculated see Appendix C, Table C-1	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, <i>continued</i> Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, <i>continued</i>				
Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i> OPTION 2
VF _{se}	Volatilization factor of subsurface soils to enclosed space (indoor air) (mg/m ³ -air)/(mg/kg-soil)	Enter values at right		calculated see Appendix C, Table C-1
VF _{ss}	Volatilization factor of surficial soil to outdoor (ambient) air as vapors (mg/m ³ -air)/(mg/kg-soil)	Enter values at right if measured		calculated see Appendix C, Table C-1
VF _{wamb}	Volatilization factor of groundwater to ambient air (mg/m ³ -air)/(mg/L-water)	Enter values at right if measured		calculated see Appendix C, Table C-1
VF _{wes}	Volatilization factor of groundwater to enclosed space (indoor air)(mg/m ³ -air)/(mg/L-water)	Enter values at right if measured		calculated see Appendix C, Table C-1

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
W	Width (feet) contaminated source areas parallel to GW flow or wind direction, ft	site-specific measurement		Any site-specific value permissible.	Any site-specific value permissible.
θ	Dispersivity in Groundwater: (feet) θ_x Longitudinal θ_y Transverse θ_z Vertical	Calculated. Enter Values in Unshaded Cell at Far Right		θ_x _____ feet θ_y _____ feet θ_z _____ feet	θ_x _____ feet θ_y _____ feet θ_z _____ feet
θ_{air}	Ambient air mixing zone height, cm	200 (6.6 feet)		Values are not variable	
θ_{gw}	Groundwater mixing zone thickness, cm	200 (6.6 feet)		Values are not variable unless field-measured	
θ	Areal fraction of cracks in foundations/walls cm ² -cracks/cm ² -total area	0.01		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
θ_s	Bulk density of soil, g/cm ³	1.7		Values are not variable	
θ	Averaging time for vapor flux, sec	Residential/ <u>Unknown</u> 9.46 X 10 ⁸	Commercial/ <u>Industrial</u> 7.88 X 10 ⁸	Construc- <u>tion</u> 3.15 X 10 ⁷	Values are not variable
θ_{acapf}	Volumetric air content, capillary fringe soils ^{1,7,8} percent	$\theta_{\text{acapf}} = \theta_T - \theta_{\text{wcapf}}$		calculate	calculate
θ_{acrack}	Volumetric air content, foundation crack ^{.8} percent	same as θ_{as}		same as θ_{as}	same as θ_{as}
θ_{as}	Volumetric air content, vadose soils ^{1,7,8} percent	$\theta_{\text{as}} = \theta_T - \theta_{\text{ws}}$		calculate	calculate

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	<i>If applicable enter values used in unshaded cells</i>	Data Requirements OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i> OPTION 2	
θ_{eff}	Porosity, effective (use for lateral transport groundwater models; for saturated zone only) ^{1,7,8} percent	<div style="display: flex; justify-content: space-between;"> <div> <input type="checkbox"/> Clay <input type="checkbox"/> Silty clay <input type="checkbox"/> Silt <input type="checkbox"/> Clayey silt <input type="checkbox"/> Silty sand <input type="checkbox"/> Clayey sand (fine sand) <input type="checkbox"/> Clean sand (medium sand) <input type="checkbox"/> Gravel (coarse sand) </div> <div> 10% 15% 15% 15% 20% 20% 23% 26% </div> </div>		To determine soil type, analyze a minimum of 3 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, analyze a minimum of 4 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
θ_T	Porosity, total (use for volatilization models) ⁴ , percent	<div style="display: flex; justify-content: space-between;"> <div> <input type="checkbox"/> Clay <input type="checkbox"/> Silty clay <input type="checkbox"/> Silt <input type="checkbox"/> Clayey silt <input type="checkbox"/> Silty sand <input type="checkbox"/> Clayey sand (fine sand) <input type="checkbox"/> Clean sand (medium sand) <input type="checkbox"/> Gravel (coarse sand) </div> <div> 38% 36% 46% 36% 41% 38% 41% 30% </div> </div>		To determine soil type or to field-measure parameter, analyze a minimum of 3 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or to field-measure parameter, analyze a minimum of 3 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 2
θ_{wcapf}	Volumetric water content, capillary fringe soils ^{7,8} percent	$\theta_{wcapf} = \theta_T - \theta_{acapf}$ <input type="checkbox"/> Clay 37.980% <input type="checkbox"/> Silty clay 35.986% <input type="checkbox"/> Silt 45.970% <input type="checkbox"/> Clayey silt 35.986% <input type="checkbox"/> Silty sand 40.965% <input type="checkbox"/> Clayey sand (fine sand) 37.978% <input type="checkbox"/> Clean sand (medium sand) 40.965% <input type="checkbox"/> Gravel (coarse sand) 29.980%		To determine soil type of field-measured parameter, analyze minimum of 3 soil samples from same horizon as contaminated soils . Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or field-measured parameter, a, analyze minimum of 4 soil samples from same horizon as contaminated soils . Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
θ_{wcrack}	Volumetric water content, foundation crack ⁸ percent	same as θ_{ws}		same as θ_{ws}	same as θ_{ws}

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	<i>If applicable enter values used in unshaded cells</i>	<div style="text-align: center;">Data Requirements</div> <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> OPTION 1 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i> </div> <div style="width: 48%;"> OPTION 2 </div> </div>																															
θ_{ws}	Volumetric water content, vadose soils ^{1,7,8} * = DTGW, depth to groundwater	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%;"></th> <th style="width: 20%; text-align: center;">θ_{ws} DTGW*</th> <th style="width: 20%; text-align: center;">θ_{ws} DTGW*</th> </tr> <tr> <th style="text-align: left;"><u>Type</u></th> <th style="text-align: center;"><u>0 - 20 ft</u></th> <th style="text-align: center;"><u>>20 ft</u></th> </tr> </thead> <tbody> <tr> <td><input type="checkbox"/> Clay</td> <td style="text-align: center;">30%</td> <td style="text-align: center;">15%</td> </tr> <tr> <td><input type="checkbox"/> Silty clay</td> <td style="text-align: center;">25%</td> <td style="text-align: center;">12%</td> </tr> <tr> <td><input type="checkbox"/> Silt</td> <td style="text-align: center;">20%</td> <td style="text-align: center;">8%</td> </tr> <tr> <td><input type="checkbox"/> Clayey silt</td> <td style="text-align: center;">25%</td> <td style="text-align: center;">12%</td> </tr> <tr> <td><input type="checkbox"/> Silty sand</td> <td style="text-align: center;">10%</td> <td style="text-align: center;">5%</td> </tr> <tr> <td><input type="checkbox"/> Clayey sand (fine sand)</td> <td style="text-align: center;">23%</td> <td style="text-align: center;">10%</td> </tr> <tr> <td><input type="checkbox"/> Clean sand (medium sand)</td> <td style="text-align: center;">7%</td> <td style="text-align: center;">3%</td> </tr> <tr> <td><input type="checkbox"/> Gravel (coarse sand)</td> <td style="text-align: center;">7%</td> <td style="text-align: center;">3%</td> </tr> </tbody> </table>		θ_{ws} DTGW*	θ_{ws} DTGW*	<u>Type</u>	<u>0 - 20 ft</u>	<u>>20 ft</u>	<input type="checkbox"/> Clay	30%	15%	<input type="checkbox"/> Silty clay	25%	12%	<input type="checkbox"/> Silt	20%	8%	<input type="checkbox"/> Clayey silt	25%	12%	<input type="checkbox"/> Silty sand	10%	5%	<input type="checkbox"/> Clayey sand (fine sand)	23%	10%	<input type="checkbox"/> Clean sand (medium sand)	7%	3%	<input type="checkbox"/> Gravel (coarse sand)	7%	3%		To determine soil type or filed-measured parameter, analyze minimum of 3 soil samples from same horizon as contaminated soils: ____ Drilling ____ Driving ____ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or filed-measured parameter, analyze minimum of 4 soil samples from same horizon as contaminated soils: ____ Drilling ____ Driving ____ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
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WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements																									
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4																								
A	Contaminated Soil Area (ft ²)	site-specific measurement		Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ^a ___ Digging	Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ^a ___ Digging																								
AT _c	Averaging Time for carcinogens, years	Residential/ <u>Unknown</u> 70 Commercial/ <u>Industrial</u> 70 Construc- <u>tion</u> 70		Values provided are not variable																									
AT _{nc}	Averaging Time for non-carcinogens, years	Residential/ <u>Unknown</u> 30 Commercial/ <u>Industrial</u> 25 Construc- <u>tion</u> 1		Values provided are not variable																									
BC _i	Biodegradation Capacity available for constituent <i>i</i> unitless	Show values at right if calculated		calculated, see Appendix C, Table C-1, equation C.23																									
BC _T	Biodegradation Capacity for all electron acceptors in groundwater unitless	Show value at near right if calculated (to calculate, see Table C-1, equation C.23). Enter electron acceptor data at far right.		<p style="text-align: center;">Enter Electron Acceptor Concentrations Below (mg/L)</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th><th style="text-align: center;"><u>Inside Plume</u></th><th style="text-align: center;"><u>Background</u></th><th style="text-align: center;"><u>Δ</u></th></tr> </thead> <tbody> <tr> <td>Dissolved Oxygen*</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr> <td>Dissolved Sulfate*</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr> <td>Dissolved Nitrate*</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr> <td>Dissolved Iron (observed within the plume)</td><td>_____</td><td>_____</td><td>_____</td></tr> <tr> <td>Methane (observed within the plume)</td><td>_____</td><td>_____</td><td>_____</td></tr> </tbody> </table> <p>Note: Δ = concentration inside the plume minus background concentration. * = use Δ values of these parameters to calculate BC. ** = use inside-plume values to calculate BC.</p>			<u>Inside Plume</u>	<u>Background</u>	<u>Δ</u>	Dissolved Oxygen*	_____	_____	_____	Dissolved Sulfate*	_____	_____	_____	Dissolved Nitrate*	_____	_____	_____	Dissolved Iron (observed within the plume)	_____	_____	_____	Methane (observed within the plume)	_____	_____	_____
	<u>Inside Plume</u>	<u>Background</u>	<u>Δ</u>																										
Dissolved Oxygen*	_____	_____	_____																										
Dissolved Sulfate*	_____	_____	_____																										
Dissolved Nitrate*	_____	_____	_____																										
Dissolved Iron (observed within the plume)	_____	_____	_____																										
Methane (observed within the plume)	_____	_____	_____																										
BW	Body weight, adults, kg	Residential/ <u>Unknown</u> 70 Commercial/ <u>Industrial</u> 70 Construc- <u>tion</u> 70		Values provided are not variable																									

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
$C(ea)_n$	Concentration of electron acceptor n in groundwater, mg/L	Tabulate data in Appendix B		field measured	
d	Thickness of surficial soil, ft	Residential/ <u>Unknown</u> 3.28 Commercial/ <u>Industrial</u> 3.28 Construc- <u>tion</u> 3.28		Values provided are not variable	
D^{air}	Diffusion coefficient in air, cm^2/sec	chemical-and fraction-specific		see Appendix C, Table C-2	
D^{eff}_s	Effective diffusivity in vadose zone soils, cm^2/sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	
d_s	Thickness of contaminated subsurface soil (feet)	site-specific measurement	d_s : _____ Depth to top: _____ Depth to base: _____	Minimum 3 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
D^{eff}_{crack}	Effective diffusivity through foundation cracks, cm^2/sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, <i>continued</i> Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, <i>continued</i>				
Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i> OPTION 4
D_{capf}^{eff}	Effective diffusivity in capillary fringe zone cm ² /sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1
D_{ws}^{eff}	Effective diffusivity above the water table, cm ² /sec	Enter value at right if calculated by hand		calculated see Appendix C, Table C-1
D^{wat}	Diffusion coefficient in water, cm ² /sec	chemical-and fraction-specific		see Appendix C Table C-2
ED	Exposure duration, adults years	<u>Residential/</u> <u>Unknown</u> <u>Commercial/</u> 30 25 <u>Construc-</u> <u>tion</u> 1		Values shown are not variable
EF	Exposure frequency, adults days/year	<u>Residential/</u> <u>Unknown</u> <u>Commercial/</u> 350 250 <u>Construc-</u> <u>tion</u> 250		Values shown are not variable
ER	Enclosed space air exchange rate 1/sec (sec ⁻¹)	<u>Residential/</u> <u>Unknown</u> <u>Commercial/</u> 0.00014 sec ⁻¹ 0.00023 sec ⁻¹ <u>Construc-</u> <u>tion</u> -		Values shown are not variable

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 1 and Option 2, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
foc, saturated	Fraction of organic carbon content, saturated zone ³ , percent	<input type="checkbox"/> Clay 0.28% <input type="checkbox"/> Silty clay 0.25% <input type="checkbox"/> Silt 0.25% <input type="checkbox"/> Clayey silt 0.25% <input type="checkbox"/> Silty sand 0.05% <input type="checkbox"/> Clayey sand (fine sand) 0.05% <input type="checkbox"/> Clean sand (medium sand) 0.05% <input type="checkbox"/> Gravel (coarse sand) 0.05%		To determine soil type, collect a minimum of 5 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, collect a minimum of 5 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
foc, unsaturated	Fraction of organic carbon content, unsaturated zone ^{1,9}	<input type="checkbox"/> Clay 0.55% <input type="checkbox"/> Silty clay 0.50% <input type="checkbox"/> Silt 0.50% <input type="checkbox"/> Clayey silt 0.50% <input type="checkbox"/> Silty sand 0.10% <input type="checkbox"/> Clayey sand (fine sand) 0.10% <input type="checkbox"/> Clean sand (medium sand) 0.10% <input type="checkbox"/> Gravel (coarse sand) 0.10%		To determine soil type, collect a minimum of 5 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, collect a minimum of 5 soil samples from same horizon as contaminated soils but from uncontaminated areas (use average values): Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements																			
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4																		
H	Henry's Law Constant (dimensionless, L-H ₂ O/L-air)	chemical-and fraction-specific see Appendix C Table C-2		Values are not variable																			
h_{capf}	Thickness of capillary fringe (feet) ^{1, 2} $L_{\text{GW}} - h_v = h_{\text{capf}}$	<table border="0"> <tr> <td>Saturated Medium</td><td>Capillary Fringe Thickness (feet)</td></tr> <tr> <td><input type="checkbox"/> Clay</td><td>5</td></tr> <tr> <td><input type="checkbox"/> Silty clay</td><td>4</td></tr> <tr> <td><input type="checkbox"/> Silt</td><td>3</td></tr> <tr> <td><input type="checkbox"/> Clayey silt</td><td>4</td></tr> <tr> <td><input type="checkbox"/> Silty sand</td><td>2</td></tr> <tr> <td><input type="checkbox"/> Clayey sand (fine sand)</td><td>1.5</td></tr> <tr> <td><input type="checkbox"/> Clean sand (medium sand)</td><td>0.8</td></tr> <tr> <td><input type="checkbox"/> Gravel (coarse sand)</td><td>0.25</td></tr> </table>	Saturated Medium	Capillary Fringe Thickness (feet)	<input type="checkbox"/> Clay	5	<input type="checkbox"/> Silty clay	4	<input type="checkbox"/> Silt	3	<input type="checkbox"/> Clayey silt	4	<input type="checkbox"/> Silty sand	2	<input type="checkbox"/> Clayey sand (fine sand)	1.5	<input type="checkbox"/> Clean sand (medium sand)	0.8	<input type="checkbox"/> Gravel (coarse sand)	0.25		To determine soil type, collect a minimum of 5 soil samples from top of saturated zone (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <i>Field measurements are not permissible.</i>	To determine soil type, collect a minimum of 5 soil samples from top of saturated zone (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <i>Field measurements are not permissible.</i>
Saturated Medium	Capillary Fringe Thickness (feet)																						
<input type="checkbox"/> Clay	5																						
<input type="checkbox"/> Silty clay	4																						
<input type="checkbox"/> Silt	3																						
<input type="checkbox"/> Clayey silt	4																						
<input type="checkbox"/> Silty sand	2																						
<input type="checkbox"/> Clayey sand (fine sand)	1.5																						
<input type="checkbox"/> Clean sand (medium sand)	0.8																						
<input type="checkbox"/> Gravel (coarse sand)	0.25																						
h_v	Thickness of vadose zone, ft	site-specific measurement		Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging																		

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
I	Infiltration rate (feet/year) ⁷	<input type="checkbox"/> Clayey soils, unpaved site: I = (5%) X Annual Precipitation <input type="checkbox"/> Sandy soils, unpaved site: I = (10%) X Annual Precipitation <input type="checkbox"/> Paved site: I = (0.55%) X Annual Precipitation	Enter annual precip. in inches/year here: _____ Enter I here: _____	To determine soil or ground cover type, collect a minimum of 5 samples. It is permissible to use the formulas shown in column 3 provided there are no leaky utility lines or other sources of artificial recharge.	To determine soil or ground cover type, collect a minimum of 5 samples. It is permissible to use the formulas shown in column 3 provided there are no leaky utility lines or other sources of artificial recharge.
i	Hydraulic gradient ft/ft	Site-specific measurement.	Value _____ Range _____ _____	Measured for all groundwater monitoring rounds using a minimum of 5 measurement points. _____ # Locations and rounds measured for <i>i</i>	Measured for all groundwater monitoring rounds using a minimum of 5 measurement points. _____ # Locations and rounds measured for <i>i</i>
IR _{air-ind}	Inhalation rate, daily indoor, m ³ /day	Residential/ <u>Unknown</u> 20 Commercial/ <u>Industrial</u> 20 Construc- <u>tion</u> -		Values are not variable	
IR _{air-out}	Inhalation rate, daily outdoor, m ³ /day	Residential/ <u>Unknown</u> 20 Commercial/ <u>Industrial</u> 20 Construc- <u>tion</u> 10		Values are not variable	
IR _{soil}	Ingestion rate of soil, mg/day	Residential/ <u>Unknown</u> 114 Commercial/ <u>Industrial</u> 50 Construc- <u>tion</u> 100		Values are not variable	
IR _{water}	Ingestion rate, daily, liters/day	Residential/ <u>Unknown</u> 2 Commercial/ <u>Industrial</u> 1 Construc- <u>tion</u> -		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
K	Hydraulic conductivity feet/day ^{4, 5}	Must be field-measured	If measured, enter range of values: _____ _____ _____ Enter average value: _____	<input type="checkbox"/> Perform slug tests at 3 locations (for shallow aquifers only), or drawdown tests at an appropriate number of locations. Use representative values. _____ # Locations measured for each above, and identity of the locations.	<input type="checkbox"/> Perform slug tests at 4 locations (for shallow aquifers only), or drawdown tests at an appropriate number of locations.. Use representative values. _____ # Locations measured for each above, and identity of the locations.
Kd or k _s	Distribution coefficient, mL/g, L/kg	Show value for each constituent at right if calculating by hand		calculated: Kd = Koc X foc	
Koc	Adsorption coefficient, mL/g, L/kg	chemical-and fraction-specific see Appendix C, Table C-2		Values are not variable	
L _B	Enclosed space volume/ infiltration area ratio, cm	<u>Residential/</u> <u>Unknown</u> <u>Commercial/</u> 200 <u>Industrial</u> 300 <u>Construc-</u> <u>tion</u> -		Values are not variable	
L _{crack}	Foundation or wall thickness, cm	<u>Residential/</u> <u>Unknown</u> <u>Commercial/</u> 15 <u>Industrial</u> 15 <u>Construc-</u> <u>tion</u> -		Values are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
L _{GW}	Depth to groundwater, ft h _v + h _{capr} = L _{GW}	site-specific measurement		Minimum 5 locations for each monitoring round. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 5 locations for each monitoring round. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
L _P	Length of Groundwater Contaminant Plume (feet)	site-specific measurement		Minimum 3 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 4 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
L _s	Depth to contaminated soil, ft	site-specific measurement	Top: _____ Base: _____	Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging	Minimum 5 locations. Enter the # of locations: ___ Drilling ___ Driving ___ Digging
M	Soil to skin adherence factor, mg/cm ²	Residential/ <u>Unknown</u> 0.5 Commercial/ <u>Industrial</u> 0.5 Construc- <u>tion</u> 0.5		Values are not variable	
P _e	Particulate emission rate, g/cm ² -sec	6.9 X 10 ⁻¹⁴		Value shown is not variable	
R	Retardation Factor, unitless	If calculated by hand, show values at right		calculated, see equation C.27	
RAF _d	Relative absorption factor, dermal, (volatiles/ PAHs)	Residential/ <u>Unknown</u> 0.5/0.05 Commercial/ <u>Industrial</u> 0.5/0.05 Construc- <u>tion</u> 0.5/0.05		Values shown are not variable	
RAF _o	Relative absorption factor, oral, unitless	Residential/ <u>Unknown</u> 1.0 Commercial/ <u>Industrial</u> 1.0 Construc- <u>tion</u> 1.0		Values shown are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements
				<div> <div>OPTION 3</div> <div>☒ <i>Mark the spaces provided or enter values, ☒, where applicable</i></div> <div>☒ <i>For Field-Measured parameters, use average and representative values.</i></div> </div> <div>OPTION 4</div>
RBSL _i	Risk-based screening level for media “i” (mg/kg-soil; mg/L-water; or ug/m ³)			chemical-, media-, and exposure route-specific
RfD _i	Reference Dose, inhalation, mg/kg-day	chemical-and fraction-specific see Appendix C, Table C-2		Values are not variable
RfD _o	Reference Dose, oral, mg/kg-day	chemical-and fraction-specific see Appendix C, Table C-2		Values are not variable
SA	Skin surface area cm ²	Residential/ <u>Unknown</u> 5800 Commercial/ <u>Industrial</u> 5800 Construc- <u>tion</u> 5800		Values are not variable
SF _i	Cancer slope factor, inhalation (mg/kg-day) ⁻¹	chemical-specific see Appendix C, Table C-2		Values are not variable
SF _o	Cancer slope factor, oral (mg/kg-day) ⁻¹	chemical-specific see Appendix C, Table C-2		Values are not variable
TER	Target Excess Lifetime Cancer Risk, unitless	Residential/ <u>Unknown</u> 10 ⁻⁶ Commercial/ <u>Industrial</u> 10 ⁻⁶ Construc- <u>tion</u> 10 ⁻⁶		Values shown are not variable
THQ	Target Hazard Quotient, unitless	Residential/ <u>Unknown</u> 1.0 Commercial/ <u>Industrial</u> 1.0 Construc- <u>tion</u> 1.0		Values shown are not variable

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
U _{air}	Wind speed above ground surface in ambient mixing zone (cm/sec)	225		Value shown is not variable	
U _{darcy}	Groundwater Darcy velocity (feet/day)	site-specific measurement = Ki		Calculated only if criteria for i & K are met.	Calculated only if criteria for i & K are met.
UF _n	Utilization Factor for electron acceptor <i>n</i> (i.e., mass ratio of electron acceptor to hydrocarbon consumed in biodegradation reactions; unitless).	Values shown at far right are for BTEX only and are not variable. Check cell at right if UFs are used.		Oxygen 3.14 Nitrate 4.90 Sulfate 4.6 Ferrous Iron 21.8 Methane 0.78	
U _{tran}	Groundwater Transport Velocity (feet/day)	site-specific measurement = Ki/θ _{eff}		Calculated only if criteria for i & K are met.	Calculated only if criteria for i & K are met.
VF _{samb}	Volatilization factor of subsurface soils to ambient air (mg/m ³ -air)/(mg/kg-soil)	If calculated by hand, enter values at right		calculated see Appendix C, Table C-1	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
VF _{se}	Volatilization factor of subsurface soils to enclosed space (indoor air) (mg/m ³ -air)/(mg/kg-soil)	If calculated by hand, enter values at right			calculated see Appendix C, Table C-1
VF _{ss}	Volatilization factor of surficial soil to outdoor (ambient) air as vapors (mg/m ³ -air)/(mg/kg-soil)	Enter values at right if measured			calculated see Appendix C, Table C-1
VF _{wamb}	Volatilization factor of groundwater to ambient air (mg/m ³ -air)/(mg/L-water)	If calculated by hand, enter values at right			calculated see Appendix C, Table C-1
VF _{wesp}	Volatilization factor of groundwater to enclosed space (indoor air)(mg/m ³ -air)/(mg/L-water)	If calculated by hand, enter values at right			calculated see Appendix C, Table C-1

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
W	Width (feet) contaminated source areas parallel to GW flow or wind direction	site-specific measurement		Any site-specific value permissible.	Any site-specific value permissible.
θ	Dispersivity in Groundwater: (feet) θ_x Longitudinal θ_y Transverse θ_z Vertical	Calculated. Enter Values in Unshaded Cell at Far Right		θ_x _____ feet θ_y _____ feet θ_z _____ feet	θ_x _____ feet θ_y _____ feet θ_z _____ feet
θ_{air}	Ambient air mixing zone height, cm	200 (6.6 feet)		Values shown are not variable	
θ_{gw}	Groundwater mixing zone thickness, cm	200 (6.6 feet)		Values shown are not variable	
θ	Areal fraction of cracks in foundations/walls cm ² -cracks/cm ² -total area	0.01		Values shown are not variable	
θ_s	Bulk density of soil, g/cm ³	1.7		Values shown are not variable	

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, *continued*
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, *continued*

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
τ	Averaging time for vapor flux, sec	Residential/ Unknown 9.46 X 10 ⁸	Commercial/ Industrial 7.88 X 10 ⁸	Construc- tion 3.15 X 10 ⁷	Values shown are not variable
θ_{acapf}	Volumetric air content, capillary fringe soils ^{1,7,8}	$\theta_{\text{acapf}} = \theta_{\text{T}} - \theta_{\text{wcapf}}$		calculate	calculate
θ_{acrack}	Volumetric air content, foundation crack ⁸	same as θ_{as}		same as θ_{as}	same as θ_{as}
θ_{as}	Volumetric air content, vadose soils ^{1,7,8}	$\theta_{\text{as}} = \theta_{\text{T}} - \theta_{\text{ws}}$		calculate	calculate
θ_{eff}	Porosity, effective (use for lateral transport groundwater models; for saturated zone only) ^{1,7,8}	<input type="checkbox"/> Clay 10% <input type="checkbox"/> Silty clay 15% <input type="checkbox"/> Silt 15% <input type="checkbox"/> Clayey silt 15% <input type="checkbox"/> Silty sand 20% <input type="checkbox"/> Clayey sand (fine sand) 20% <input type="checkbox"/> Clean sand (medium sand) 23% <input type="checkbox"/> Gravel (coarse sand) 26%		To determine soil type, analyze a minimum of 3 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type, analyze a minimum of 4 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, continued
Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, continued

Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements	
				OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>	OPTION 4
θ_T	Porosity, total (use for volatilization models) ⁴	<input type="checkbox"/> Clay 38% <input type="checkbox"/> Silty clay 36% <input type="checkbox"/> Silt 46% <input type="checkbox"/> Clayey silt 36% <input type="checkbox"/> Silty sand 41% <input type="checkbox"/> Clayey sand (fine sand) 38% <input type="checkbox"/> Clean sand (medium sand) 41% <input type="checkbox"/> Gravel (coarse sand) 30%		To determine soil type or to field-measure parameter, analyze a minimum of 3 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or to field-measure parameter, analyze a minimum of 4 soil samples from same horizon as contaminated soils (use average values). Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
θ_{wcapf}	Volumetric water content, capillary fringe soils ^{7,8}	$\theta_{wcapf} = \theta_T - \theta_{acapf}$ <input type="checkbox"/> Clay 37.980% <input type="checkbox"/> Silty clay 35.986% <input type="checkbox"/> Silt 45.970% <input type="checkbox"/> Clayey silt 35.986% <input type="checkbox"/> Silty sand 40.965% <input type="checkbox"/> Clayey sand (fine sand) 37.978% <input type="checkbox"/> Clean sand (medium sand) 40.965% <input type="checkbox"/> Gravel (coarse sand) 29.980%		To determine soil type of field-measured parameter, analyze a minimum of 5 soil samples from same horizon as contaminated soils . Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or field-measured parameter, a, analyze a minimum of 5 soil samples from same horizon as contaminated soils . Enter the # of locations: ___ Drilling ___ Driving ___ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.

WORKSHEET # 2: Data Requirements for Option 1 through Option 4, <i>continued</i> Data Requirements for Site-Specific Parameters, and Exposure and Cross-Media Transport Parameters for Option 3 and Option 4, <i>continued</i>																																			
Parameter Symbol	Parameter Definition and Units	Permissible Values and Instructions <i>Mark the spaces provided, ☒, where applicable</i>	If applicable enter values used in unshaded cells	Data Requirements OPTION 3 <i>☒ Mark the spaces provided or enter values, ☒, where applicable</i> <i>☒ For Field-Measured parameters, use average and representative values.</i>																															
θ_{wcrack}	Volumetric water content, foundation crack ⁸	same as θ_{ws}		same as θ_{ws}	same as θ_{ws}																														
θ_{ws}	Volumetric water content, vadose soils ^{1,7,8} * Depth to Groundwater	<table border="0"> <tr> <td>Soil</td> <td>θ_{ws} DTGW*</td> <td>θ_{ws} DTGW*</td> </tr> <tr> <td><u>Type</u></td> <td><u>0 - 20 ft</u></td> <td><u>≥20 ft</u></td> </tr> <tr> <td><input type="checkbox"/> Clay</td> <td>30%</td> <td>15%</td> </tr> <tr> <td><input type="checkbox"/> Silty clay</td> <td>25%</td> <td>12%</td> </tr> <tr> <td><input type="checkbox"/> Silt</td> <td>20%</td> <td>8%</td> </tr> <tr> <td><input type="checkbox"/> Clayey silt</td> <td>25%</td> <td>12%</td> </tr> <tr> <td><input type="checkbox"/> Silty sand</td> <td>10%</td> <td>5%</td> </tr> <tr> <td><input type="checkbox"/> Clayey sand (fine sand)</td> <td>23%</td> <td>10%</td> </tr> <tr> <td><input type="checkbox"/> Clean sand (medium sand)</td> <td>7%</td> <td>3%</td> </tr> <tr> <td><input type="checkbox"/> Gravel (coarse sand)</td> <td>7%</td> <td>3%</td> </tr> </table>	Soil	θ_{ws} DTGW*	θ_{ws} DTGW*	<u>Type</u>	<u>0 - 20 ft</u>	<u>≥20 ft</u>	<input type="checkbox"/> Clay	30%	15%	<input type="checkbox"/> Silty clay	25%	12%	<input type="checkbox"/> Silt	20%	8%	<input type="checkbox"/> Clayey silt	25%	12%	<input type="checkbox"/> Silty sand	10%	5%	<input type="checkbox"/> Clayey sand (fine sand)	23%	10%	<input type="checkbox"/> Clean sand (medium sand)	7%	3%	<input type="checkbox"/> Gravel (coarse sand)	7%	3%		To determine soil type or filed-measured parameter, analyze a minimum of 5 soil samples from same horizon as contaminated soils: ____ Drilling ____ Driving ____ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.	To determine soil type or filed-measured parameter, analyze a minimum of 5 soil samples from same horizon as contaminated soils: ____ Drilling ____ Driving ____ Digging <input type="checkbox"/> Value selected from permissible values. <input type="checkbox"/> Field-Measured.
Soil	θ_{ws} DTGW*	θ_{ws} DTGW*																																	
<u>Type</u>	<u>0 - 20 ft</u>	<u>≥20 ft</u>																																	
<input type="checkbox"/> Clay	30%	15%																																	
<input type="checkbox"/> Silty clay	25%	12%																																	
<input type="checkbox"/> Silt	20%	8%																																	
<input type="checkbox"/> Clayey silt	25%	12%																																	
<input type="checkbox"/> Silty sand	10%	5%																																	
<input type="checkbox"/> Clayey sand (fine sand)	23%	10%																																	
<input type="checkbox"/> Clean sand (medium sand)	7%	3%																																	
<input type="checkbox"/> Gravel (coarse sand)	7%	3%																																	

References for Worksheet #2: ¹ Groundwater Services, Inc. (GSI), 1996a; ³ Derived from reference 1 based on solubility of foc in saturated zone; ² Brady, N.C, 1974; ⁴ Freeze and Cherry, 1979; ⁵ DERR case files; ⁶ Spitz and Moreno 1996; ⁷ Connor, et al., 1996; ⁸ ASTM, 1994.

Worksheet #2: Data Requirements for Option 1 through Option 4, *continued*
Justification for Departure from Worksheet #2 Requirements

INSTRUCTIONS: Identify each item from the preceding Worksheet #2, that does not conform to the specified requirements in Worksheet #2. Describe why the requirement was not conformed to, and the impact the nonconformity has on evaluating site conditions and exposure pathways.

Number of Sampling Locations:

Hydraulic Conductivity Measurements:

Number of Monitoring Locations:

Number of Years of Monitoring:

Plume Stability:

Determination of Attenuation Mechanisms:

Exposure Parameters:

Cross-Media Transport Parameters:

Worksheet #2: Data Requirements for Option 1 through Option 4, *continued*
Justification for Departure from Worksheet #2 Requirements, *continued*

Modeling Requirements:

General Deficiencies in Worksheet #2:

Other:

Site Name: _____
Site Location: _____
Facility ID: _____

Worksheet #3: Site Conceptual Exposure Model (modified from GSI, 1995)

INSTRUCTIONS

1. Mark the small boxes if the specified condition is applicable
2. Fill in the shutoff valves to indicate that exposure pathway is **NOT** complete. Exposure pathway may **not** be complete due to source removal, control, and/or treatment
3. For each complete pathway, identify the cleanup options.

CAUSES of RELEASE

IMPACTED MEDIUM

TRANSPORT MECHANISM

EXPOSURE PATHWAY

POTENTIAL RECEPTORS*

CLEANUP OPTIONS

(check applicable)

____ Product Storage (tanks/UST)

____ Piping

____ Dispenser

____ Other

☐ Surface Soil <3 ft deep**

☐ Subsurface Soil >3 ft deep**

☐ Dissolved Groundwater Plume

☐ Free Phase Liquid Plume***

☐ Surface soils, Sediments, or Surface Water

☐ Volatilization and Dust Transport

☐ Volatilization to Outdoor Air

☐ Volatilization to Indoor Air

☐ Leaching and/or Groundwater Transport

☐ Mobile Free Phase Migration

☐ Storm water/Surface Water Transport

☐ **SOIL**
Dermal Contact/Ingestion

☐ **AIR**
Inhalation of Vapors or Particulates

☐ **GROUNDWATER**
Potable Water Use or Property Boundary

☐ **SURFACE WATER**
Recreational Use/ Sensitive Habitat

Exposed Receptors

☐ On-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

☐ Off-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

Exposed Persons

☐ On-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

☐ Off-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

Groundwater Users

☐ On-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

☐ Off-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

Surface Water Users

☐ On-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ None ☐

☐ Off-site: Residential ☐ nonresidential ☐
Sensitive Habitat ☐ construction worker ☐

☐ Complete ☐ Current
Pathway ☐ Potential

Action Required? Yes ___ No ___
if YES, list cleanup options below:

☐ Complete ☐ Current
Pathway ☐ Potential

Action Required? Yes ___ No ___
if YES, list cleanup options below:

☐ Complete ☐ Current
Pathway ☐ Potential

Action Required? Yes ___ No ___
if YES, list cleanup options below:

☐ Complete ☐ Current
Pathway ☐ Potential

Action Required? Yes ___ No ___
if YES, list cleanup options below:

Notes:

* "Potential" refers to a projection of 5 to 10 years

** Evaluate potential for subsurface soil to be excavated and become surface soil

*** Free Product is a source that must be eliminated or controlled. See Free Product Removal Report in Subsurface Investigation, Appendix D.

Figure A-1: Hypothetical Exposure Pathways and Initial Screening Criteria

Use this figure as a guide only for evaluating exposure. Do not complete or submit this form. This figure may be helpful in evaluating uncertainties and making risk management decisions and may be useful for completing Section K of Worksheet #1, Appendix A.

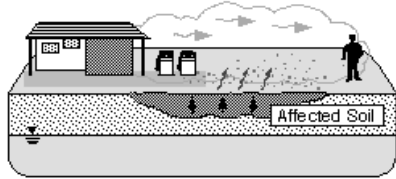
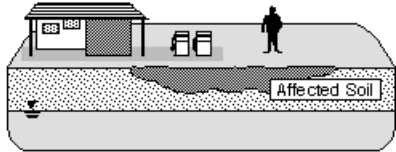
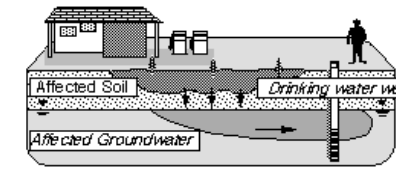
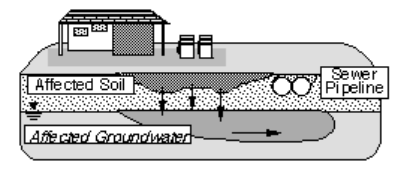
		EXPOSURE PATHWAY SCREENING CRITERIA		
Exposure Pathway and Remedy Performance Standard		Source Zone	Transport Mechanism	Receptor Point
 <p>Air Exposure</p> <p>Prevent exceedance of applicable risk limits due to vapor or dust inhalation.</p>	<ul style="list-style-type: none">No affected soils exceeding Tier 1 criteria within 15 ft of ground surface.	<ul style="list-style-type: none">Soil vapor flux to surface does not exceed air exposure limit.Air dispersion effects reduce ambient dust/vapors to below air exposure limit.	<ul style="list-style-type: none">Ambient Air: Concentrations at POE are below applicable exposure limits.Indoor Air: No enclosed building located over affected soil zone.	
 <p>Soil Exposure</p> <p>Prevent exceedance of applicable risk limits due to human exposure via incidental soil ingestion or dermal contact</p>	<ul style="list-style-type: none">No affected soils at ground surface exceeding Tier 1 criteria.	-----	-----	
 <p>Groundwater Ingestion</p> <p>Prevent exceedance of drinking water limits in water supply wells completed within underlying water-bearing strata.</p>	<ul style="list-style-type: none">No affected groundwater exceeding drinking water limits (federal MCLs).No affected soils exceeding Tier 1 criteria.	<ul style="list-style-type: none">Affected groundwater plume stable or shrinking and does not reach applicable POE.	<ul style="list-style-type: none">Plume concentrations at POE are below drinking water limits.	
 <p>Subsurface Utilities</p> <p>Prevent property damage, explosive vapor condition, and contaminant migration via subsurface utility corridor. Remove NAPL to extent practicable.</p>	<ul style="list-style-type: none">No affected soils or groundwater in contact with subsurface utilities. No NAPL present in soils or groundwater.	<ul style="list-style-type: none">Affected groundwater plume stable or shrinking and does not reach subsurface utility.	<ul style="list-style-type: none">For vapors, soil and groundwater concentrations within 15 ft beneath subsurface utility are below Tier 1 SL for soil-to-air and groundwater-to-air pathways.	
NOTES:				
<div>1) An exposure pathway screening evaluation is to be conducted prior to Tier 2 Options 1 through 4 to identify pathways of concern for each site. For each Tier 2 Risk Assessment, Worksheet 3 (SCM) must be completed to identify complete/incomplete exposure pathways without consideration of existing or proposed control measures. An exposure pathway is considered <i>incomplete</i> if the relevant screening criteria are satisfied for either the source zone, the transport mechanism, or the receptor point. Pathways which do not meet screening criteria are either currently or potentially <i>complete</i> and will require further evaluation and/or response.</div> <div>2) POE = Point of Exposure NAPL = Non-Aqueous Phase Liquid</div> <div>Tier 1 Criteria = Utah's Tier 1 guidance (1997) s that includes pre-set screening levels and distances to receptors.</div>				

Table A-5: Guide for Evaluating Exposure

Use this table as a guide only for evaluating exposure. Do not complete or submit this form. This table may be helpful in evaluating uncertainties and making risk management decisions and may be useful for completing Section K of Worksheet #1, Appendix A.

PATHWAYS OF CONCERN	PATHWAY SCREENING CRITERIA	CURRENT vs. POTENTIAL EXPOSURE	PATHWAY STATUS
AIR EXPOSURE PATHWAYS			
■ Subsurface Soil-to-Ambient Air	Subsurface soil contamination?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes-----→ Affected soils exposed at ground surface (no cover)?	<input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
■ Subsurface Soil: Vapor Intrusion-to-Indoor Air	Subsurface soil beneath existing building?	<input type="checkbox"/> No-----→ Buildings expected to be built over contamination? <input type="checkbox"/> Yes -----→ Observed or suspected soil vapor impact?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes-----→ Complete/Potential Exposure <input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
■ GW-to-Ambient Air	GW contamination?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes-----→ Affected plume beneath exposed surface area (no cover, i.e. bare soil)?	<input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
■ GW: Vapor Intrusion-to-Indoor Air	GW contamination beneath existing building?	<input type="checkbox"/> No-----→ Buildings expected to be built over contamination? <input type="checkbox"/> Yes -----→ Observed or suspected vapor impact?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes-----→ Complete/Potential Exposure <input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
GROUNDWATER EXPOSURE PATHWAYS			
■ GW Ingestion: On-Site	GW impacted in excess of Tier 1 criteria <i>and</i> existing water supply well located on-site?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes -----→ On-site water supply well impacted by site constituents?	<input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
■ GW Ingestion: Off-Site	GW impacted in excess of Tier 1 criteria <i>and</i> plume presently off-site or likely to migrate off-site?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes -----→ Plume in expanding condition <i>and</i> existing water supply well within 250 ft downgradient?	<input type="checkbox"/> No -----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
■ Soil-to-GW Impact	Surface or subsurface soil contamination <i>and</i> either on-site or off-site GW ingestion pathway complete?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes -----→ Affected soil zone exposed to rainfall infiltration (no cover)?	<input type="checkbox"/> No -----→ Complete/Potential Exposure <input type="checkbox"/> Yes -----→ Complete/Current Exposure*
■ GW Dermal Contact: Construction Worker in ROW	GW ingestion POE is across ROW <i>and</i> GW plume concentrations beneath ROW exceed Tier 1 criteria within 0-15 ft bgs?	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes -----→ ROW earthwork activity underway or proposed?	<input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes-----→ Complete/Current Exposure*
NOTES: GW = Groundwater ROW = Right of Way POE = Point of Exposure NAPL = Non-Aqueous Phase Liquid bgs = Below Ground Surface * May require emergency abatement			

Table A-5, *continued*: Guide for Evaluating Exposure

Use this table as a guide only for evaluating exposure. Do not complete or submit this form. This table may be helpful in evaluating uncertainties and making risk management decisions and may be useful for completing Section K of Worksheet #1, Appendix A.

PATHWAYS OF CONCERN	PATHWAY SCREENING CRITERIA	CURRENT VS. POTENTIAL	PATHWAY STATUS
SOIL EXPOSURE PATHWAYS			
■ Surface Soil Dermal Contact, Vapor/Dust Inhalation: <i>Residential or Commercial Workers</i>	Surface or subsurface soil contamination?	<input type="checkbox"/> No-----→Is subsurface soil likely to be excavated?----- <input type="checkbox"/> Yes-----→Site earthwork activity underway or proposed?--	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes----→Complete/Potential Exposure <input type="checkbox"/> No → Complete/Potential Exposure <input type="checkbox"/> Yes----→ Complete/Current Exposure*
■ Surface Soil Dermal Contact, Vapor/Dust Ingestion: <i>Construction Worker</i>	Surface or subsurface soil contamination?	<input type="checkbox"/> No-----→Is subsurface soil likely to be excavated?----- <input type="checkbox"/> Yes----→Site earthwork activity underway or proposed?--	<input type="checkbox"/> No-----→ Incomplete Pathway <input type="checkbox"/> Yes----→Complete/Potential Exposure <input type="checkbox"/> No----→Complete/Potential Exposure <input type="checkbox"/> Yes----→Complete/Current Exposure*
UNDERGROUND UTILITY IMPACTS			
■ Soil Impacts on Utilities	Soil contamination in contact with or within 15 feet below underground utility?	<input type="checkbox"/> No-----→-----→ Incomplete Pathway <input type="checkbox"/> Yes ----→Soil vapors exceed 20% LEL adjacent to utility--- line or utility susceptible to physical damage?	<input type="checkbox"/> No-----→ Complete/Potential Exposure <input type="checkbox"/> Yes----→Complete/Current Exposure*
■ GW / NAPL Impacts on Utilities	NAPL or GW containing BTEXN in excess of 30 mg/L in contact with or within 15 ft below underground utility?	<input type="checkbox"/> No-----→-----→ Incomplete Pathway <input type="checkbox"/> Yes --→Soil vapors exceed 20% LEL adjacent to utility --→ line or utility susceptible to physical damage?	<input type="checkbox"/> No -----→Complete/Potential Exposure <input type="checkbox"/> Yes ----→Complete/Current Exposure*
NOTES: GW = Groundwater ROW = Right of Way POE = Point of Exposure NAPL = Non-Aqueous Phase Liquid bgs = Below Ground Surface * May require emergency abatement			

Worksheet #4a

Plume Stability Evaluation Procedures and Results

Facility Name and Location:

Date Completed:

Facility ID:

Completed By:

INSTRUCTIONS

STEP 1

Use this Worksheet 4a to show the final results of your mass balance and plume stability calculations. Complete Worksheets 4b through 4e, as applicable, to ensure that your final conclusions regarding contaminant reduction are as accurate as possible.

Discuss groundwater fluctuations, biodegradation capacity, or other phenomena to support your conclusions regarding plume stability. Discuss the source of data used and show applicable figures in Appendix B.

STEP 2

Check the worksheet(s) below that apply to the site:

- ☐ Worksheet 4a: Plume Stability Results (this page)
- ☐ Worksheet 4b: Mass Calculations for Dissolved Phase
- ☐ Worksheet 4c: Mass Calculations for Adsorbed Phase
- ☐ Worksheet 4d: Percent of Average Decrease of Dissolved Contaminant Concentrations
- ☐ Worksheet 4e: Statistical Evaluation of Plume Stability

STEP 3

Discuss the results of each Worksheet (4b through 4e) as they relate to your Tier 2 Risk Assessment and plume stability in each medium.

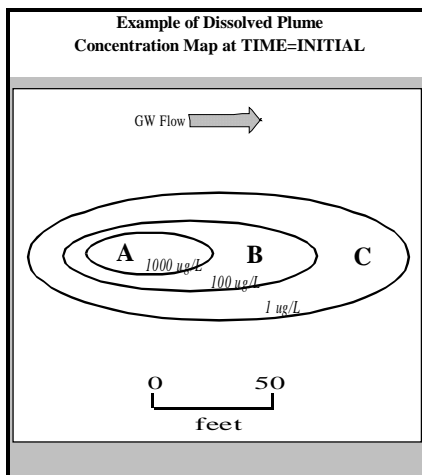
WORKSHEET #4b

Mass Calculations for Initial and Ending Dissolved Phase

Facility Name and Location:
Facility ID:

Constituent(s) Evaluated: _____

Date Completed:
Completed By:



INSTRUCTIONS

1. Evaluate applicable, appropriate and representative individual and/or combined constituents (e.g., benzene, total BTEXN, TPH, other) that, for example, exceed Tier 1 criteria or MCLs. *Identify constituent(s) evaluated.*
2. Construct site-specific GW contamination concentrations contour maps, like the example shown, for initial and ending times. Divide the map into discrete sections or "areas" and calculate the mass in each area, for each time interval, as shown.
3. If you use this spreadsheet to solve the equations, enter your site-specific data in the unshaded cells below.
4. Calculate the total mass in the dissolved phase, in each area, at TIME = INITIAL. Then, calculate the total mass in dissolved total mass in the dissolved phase, in each area, for TIME = END. *Identify what your INITIAL and ENDING times are.*
5. The plume is stable if the ending mass is less the same as the initial mass. The plume is decreasing if the ending mass is less than the initial mass.
6. The FINAL PERCENT REDUCTION (+) or INCREASE (-) of mass is shown in the cell below.
7. If you are manually calculating mass, use the equations below.

EQUATIONS

Mass Area(A) = (Area of Area A)(thickness of plume in Area A, ft)(ave conc in Area A, mg/L)(total porosity)(unit mass conversion)
 Mass Area(B) = (thickness of plume in Area B, ft)[(Area of B)-(Area of A)](ave. concn. Area B, mg/L)(total porosity)(unit mass conversion)
 Mass Area(C) = (thickness of plume in Area C, ft)[(Area of C)-(Area of B)](ave. concn. Area C, mg/L)(total porosity)(unit mass conversion)
 Unit Mass Conversion = (1000 L/m³)(0.02832 m³/ft³)(1g/1000mg)(1kg/1000g)

GW: FINAL % REDUCTION (+) OR INCREASE (-) shown below

58.47%

TIME = INITIAL Enter Beginning Date Here: _____

GW Area "A"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
45	20	3	5	0.38	0.145

GW Area "B"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet)	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
105	65	3	2	0.38	0.383

GW Area "C"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
150	110	3	0.3	0.38	0.094

**TIME=INITIAL:
TOTAL MASS IN DISSOLVED
PHASE SHOWN BELOW (kg):
0.622**

TIME = END Enter Ending Date Here: _____

GW Area "A"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
85	40	3	1	0.38	0.110

GW Area "B"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
130	65	3	0.5	0.38	0.082

GW Area "C"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
235	80	3	0.2	0.38	0.067

**TIME=END:
TOTAL MASS IN DISSOLVED
PHASE SHOWN BELOW (kg):
0.258**

* Use 3 feet for GW plume thickness unless you have evidence such as vertical sampling, to prove otherwise.

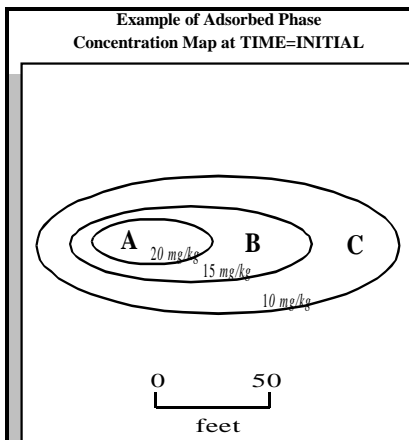
WORKSHEET #4c

Mass Calculations for Initial and Ending Adsorbed Phase

Facility Name and Location:
Facility ID:

Constituent(s) Evaluated: _____

Date Completed:
Completed By:



INSTRUCTIONS

1. Evaluate applicable, appropriate and representative individual and/or combined constituents (e.g., benzene, total BTEXN, TPH, other) that, for example, exceed 1 or 10 times the background level(s) evaluated.
2. Construct site-specific soil contamination concentrations contour maps, like the example shown, for initial and ending times. Divide the map into discrete sections or "areas" and calculate the mass in each area, for each time interval, as shown.
3. If you use this spreadsheet to solve the equations, enter your site-specific data in the unshaded cells below.
4. First, calculate the total mass in the adsorbed phase, in each area, at TIME = INITIAL. Then, calculate the total mass in adsorbed phase, for each time interval, in each area, for TIME = END. Identify what your INITIAL and ENDING times are.
5. The plume is stable if the ending mass is the same as the initial mass. The plume is decreasing if the ending mass is less than the initial mass. The plume is increasing if the ending mass is greater than the initial mass.
6. The FINAL PERCENT REDUCTION (+) OR INCREASE (-) of mass is shown in the cell below.
7. If you are manually calculating mass, use the equations below.

Mass Area A = (Area of Area A)(thickness of soil plume in Area A, ft)(ave soil conc in Area A, mg/kg)(bulk density)(UMC)

Mass Area B = (thickness of soil plume in Area B, ft)[(Area of B - Area of A)](ave soil conc in Area B, mg/kg)(bulk density)(UMC)

Mass Area C = (thickness of soil plume in Area C, ft)[(Area of C - Area of B)](ave soil conc in Area C, mg/kg)(bulk density)(UMC)

Soil Mass % dec/inc: 1-(mass@end/mass@initial)

UMC, Unit Mass Conversion = (28320 cm³/ft³)(1kg/1000g)(1g/1000mg)(1kg/1000g)

FINAL RESULTS OF SOIL MASS REDUCTION OR INCREASE MASS SUMMARY (kg)

Total Mass in Soil at Time = INITIAL (kg)	Total Mass in Soil at Time = END (kg)	Final Mass Reduction/Increase in Soil
2.77	1.38	50%

TIME = INITIAL Enter Beginning Date Here: _____

Soil Area "A"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
30	20	2	20	1.7	1.155

Soil Area "B"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
60	30	2	10	1.7	1.155

Soil Area "C"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
150	75	2	0.5	1.7	0.455

**TIME=INITIAL:
TOTAL MASS IN Adsorbed PHASE
SHOWN BELOW (kg):
2.77**

TIME = END Enter Ending Date Here: _____

Soil Area "A"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
30	20	2	6	1.7	0.347

Soil Area "B"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
60	30	2	5	1.7	0.578

Soil Area "C"

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/kg)	Bulk Density (g/cm ³)	Mass in Adsorbed Phase shown below (kg)
150	75	2	0.5	1.7	0.455

**TIME=END:
TOTAL MASS IN ADSORBED
PHASE SHOWN BELOW (kg):
1.38**

* Adsorbed plume thickness must reflect the actual thickness of contaminated soil

WORKSHEET #4d

Determining Percent Decrease in Dissolved Concentrations

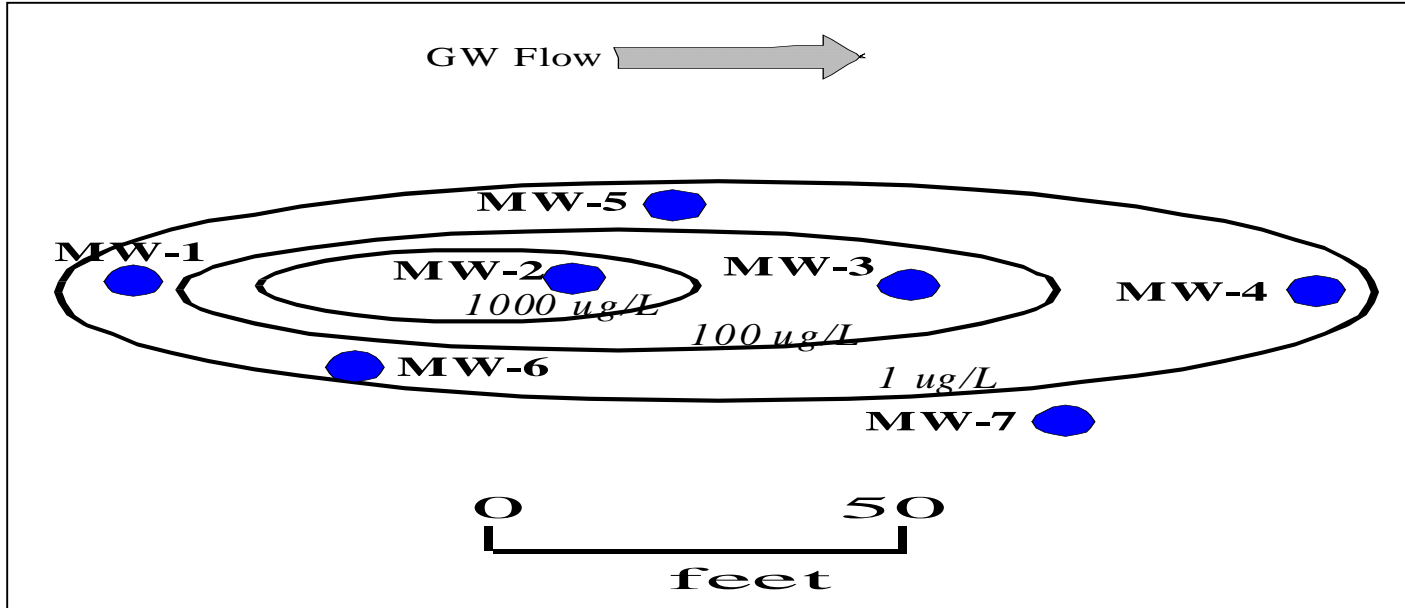
Constituent(s) Evaluated: _____

Facility Name and Location:

Facility ID:

Date Completed:

Completed By:



INSTRUCTIONS: Example of Calculating Percent Reduction of Dissolved Contamination Across a Site. Enter your data in the UNSHADED cells				
Enter Well # below	Enter Concentration at Time 1 (= baseline concentration)	Enter Concentration at Time 2	Enter Concentration at Time 3	Enter Concentration at Time 4
MW-1	1	0.75	0.75	0.51
MW-2	2	1	0.6	0.09
MW-3	5.6	4.5	2.1	0.95
MW-4	4.1	3	1.8	0.09
ENTER TOTAL # OF WELLS LISTED ABOVE	4			
TOTAL CONCENTRATION OF ALL WELLS	12.7	9.25	5.25	1.64
AVERAGE CONCENTRATION OF ALL WELLS	3.175	2.3125	1.3125	0.41
TOTAL AVERAGE CONCENTRATION	100%	73%	41%	13%
AVERAGE %	0	27%	59%	87%

FORMULAS: AVERAGE % REDUCTION = (concentration average at TIME=1)- (concentration average at TIME=2)

WORKSHEET #4e: STATISTICAL EVALUATION OF PLUME STABILITY

Site Name:
Facility ID:

Date Completed:
Completed By:

HISTORICAL GROUNDWATER DATABASE

ADEQUACY OF DATABASE FOR TREND ANALYSIS

Instructions: This form can be used to characterize a groundwater plume as either stable, diminishing, or expanding based on concentration trends. For meaningful results, the historical database should include four or more groundwater sampling events at two or more monitoring wells located inside the plume area. Evaluate database in space provided and indicate selected action (☒). **Warning: This Worksheet #4e may not be useful for fluctuating concentration trends. It may be more useful to rely on mass balance Worksheets #4a and #4b, and hydrographs such as that shown in Figure B-6 to evaluate plume stability.**

☐ **Sufficient Data Available:** Four or more independent samples (i.e., different sampling dates) are available from each well in plume area:

➤ *Complete one Statistical Analysis Worksheet (page 2 of 3) for each monitoring well in plume to evaluate trends in sampling data. Record results for all wells on Summary Worksheet (page 3 of 3).*

☐ **Insufficient Data Available:** Fewer than 4 independent samples are available from each well.

➤ *Select action:* ☐ *Conduct additional groundwater monitoring and re-evaluate, OR*
☐ *Assume expanding plume condition and proceed with risk-based site evaluation*

HISTORICAL GROUNDWATER MONITORING DATA

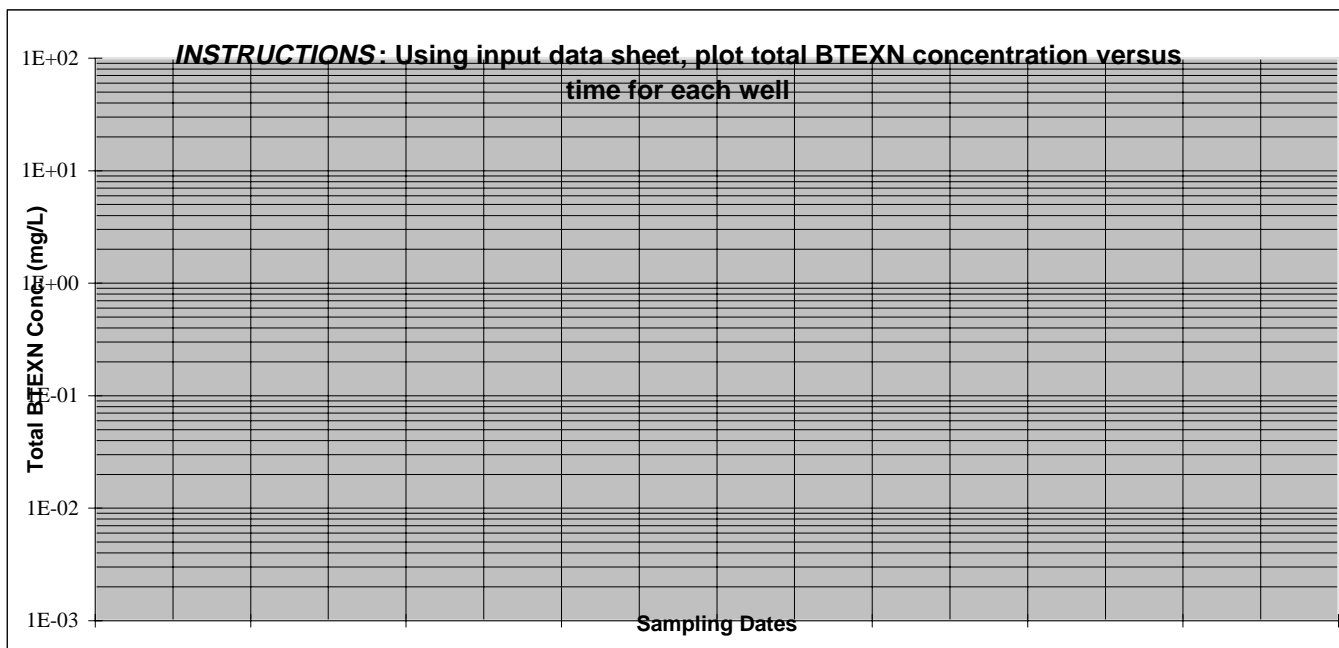
Instructions: In spaces provided below, record historical groundwater monitoring results for wells located inside plume area. Do not include upgradient wells or background wells in this stability evaluation.

WELL ID:

--	--	--	--	--	--	--	--	--	--

Sampling Event	Date	Total BTEXN Conc. (mg/L)							
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Notes: ND = Not detected; NS = Not sampled; PSH = Phase-separated hydrocarbon present.



WORKSHEET #4e: STATISTICAL EVALUATION OF PLUME STABILITY, *continued*

Site Name:
Facility ID:

Date Completed:
Completed By:

INSTRUCTIONS

The Mann-Kendall statistic can be used to define the stability condition of a groundwater plume (i.e., stable, diminishing or expanding) based on concentration trends at individual wells. For each monitoring well located in plume area for which 4 or more independent sampling events are available, follow the steps described below. Complete a separate form for each well.

Step 1: Well Data: Enter Well ID No. and total BTEXN concentrations for each sampling event (i.e. data from page 1 of 3).

Include only events for which numeric or ND values are available. Do not include Not Sampled (NS) or PSH events.

Step 2: Data Comparisons: Complete Row 1, comparing the results of Events 2, 3 etc. to Event 1, as follows:

- 1 Concentration of Event x > Event 1: Enter 1
- 1 Concentration of Event x = Event 1: Enter 0
- 1 Concentration of Event x < Event 1: Enter -1

Complete all Rows in same manner until all sampling events are complete. Sum the right hand column down to get TOTAL sum. This TOTAL value represents Mann-Kendall Statistic "S" for the data from this well.

Step 4: Results: Use Confidence Level Chart to determine % confidence in plume trend based on S value & number of sampling events.

MANN-KENDALL ANALYSIS OF PLUME

Well ID No:

Total BTEXN (mg/L)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Sum Rows
Row 1: Compare to Event 1:	→										0
Row 2: Compare to Event 2:		→									0
Row 3: Compare to Event 3:			→								0
Row 4: Compare to Event 4:				→							0
Row 5: Compare to Event 5:					→						0
Row 6: Compare to Event 6:						→					0
Row 7: Compare to Event 7:							→				0
Row 8: Compare to Event 8:								→			0
Row 9: Compare to Event 9:									→		0
Mann-Kendall Statistic (S) = TOTAL											0

CHARACTERIZATION OF GROUNDWATER PLUME BASED ON DATA FROM THIS WELL

Use the Confidence Level Chart with the Mann-Kendall Statistic computed above (S) and the number of sampling events to estimate confidence level in the presence of a plume trend (i.e., expanding plume or diminishing plume):

Confidence Level Chart							
S Value	Total No. of Sampling Events						
	4	5	6	7	8	9	10
±1							
±2			No Trend Indicated				
±3							
±4							
±5							
±6			Trend May Be Present				
±7							
±8					(70% ≤ Conf. 90%)		
±9							
±10							
±11			Trend is Present (>90% Confidence)				
±12							
±13							
±14							
±15							

Stability Evaluation Results

- ☐ **No Trend Indicated** Stable Plume
- ☐ **Trend May Be Present*** (70% ≤ Confidence < 90%):
- ☐ S < 0 Potentially Diminishing Plume
 - ☐ S > 0 Potentially Expanding Plume
- ☐ **Trend Is Present** (≥ 90% Confidence)
- ☐ S < 0 Diminishing Plume
 - ☐ S > 0 Expanding Plume

*Trend May Be Present: For this case, additional monitoring data is required to confirm presence of trend. To proceed with RBCA evaluation, assume stable plume for S < 0 and assume expanding plume for S > 0.

WORKSHEET #4e: STATISTICAL EVALUATION OF PLUME STABILITY, *continued*Site Name:
Facility ID:Date Completed:
Completed By:**SUMMARY OF RESULTS: GROUNDWATER PLUME STABILITY CONDITION****INSTRUCTIONS:**

Record results of statistical trend analysis for each monitoring well located inside plume area.
Provide a brief discussion regarding significance of findings.

RESULTS OF MANN-KENDALL ANALYSIS

Well ID.	No. of Sampling Events	Mann- Kendall Statistic, S	Plume Trend

NOTES: Plume Trend: Stable, Potentially Diminishing, Diminishing,
Potentially Expanding, or Expanding as determined from
Confidence Level Chart.

DISCUSSION

Discuss consistency of findings among wells, conclusion regarding total plume stability condition, need for
further evaluation, etc.

APPENDIX B

Site-Specific Data Requirements and Attachments

Table B-1: Data Requirements Checklist

INSTRUCTIONS

1. *Ensure you have attached all required and relevant data for each applicable Option shown below to this Appendix B.*
2. *Place each data requirement in the order shown below for Appendix B of the Tier 2 Risk Assessment report.*

Data requirements for each Option are checked below

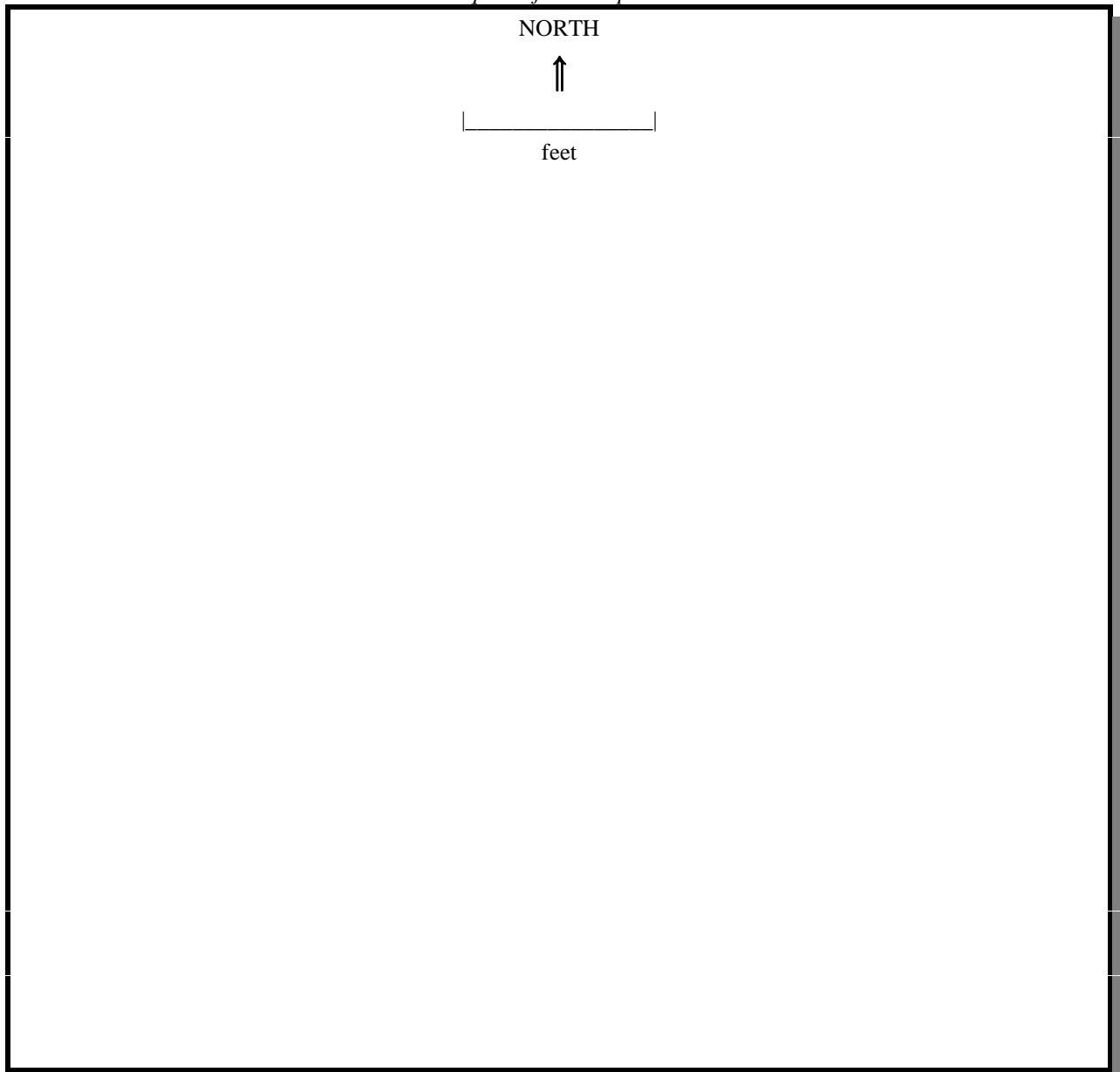
DATA REQUIREMENTS FOR EACH OPTION		OPTION 1	OPTION 2	OPTION 3	OPTION 4
Figure B-1	Site Map	✓			
Figure B-2	Vicinity Map	✓			
Figure B-3	Groundwater Elevation Maps	✓ ^a	✓		
Figure B-4	Contaminant Iso-Concentration Maps	✓ ^a	✓		
Figure B-5	Electron Acceptor or Metabolic By-Product Iso-Concentration Maps ^b	na	✓		
Figure B-6	Example Graph of Groundwater Elevation, Dissolved Oxygen and Benzene Over Time	na	✓		
Figure B-7	Example Graph of Groundwater Elevation and Free Product Thickness Over Time	na	✓		
Table B-2	Soil Closure and Confirmation Sample Analytical Results	✓			
Table B-3	Groundwater Closure Sample Analytical Results	✓ ^a	✓		
Table B-4	Groundwater Monitoring Analytical Results	na	✓		
Table B-5	Contaminant and Electron Acceptor or Metabolic By-Product Analytical Results	na	✓		
Table B-6	Logs of Monitoring Wells, Borings, Drive Points and Test Pits	na		✓	
Table B-7	Hydraulic Testing	na	✓		
Table B-8	Cross-Section Requirements	✓			
●	Subsurface Investigation Report (must contain all of the above-listed data requirements). <i>You may attach a complete report or applicable portions of the Subsurface Investigation Report in this Appendix B.</i>	✓			

NOTES:

✓^a= condition may apply if groundwater is impacted.;^a **na** = condition is not applicable or is optional.

^b = Examples of electron acceptors that may need sampling and mapping include dissolved oxygen, sulfate, nitrate and ferrous iron (Fe⁺²). Note, however, that the sampling efforts and maps are valid only for those electron acceptors that show a positive inverse correlation to contaminant plumes.

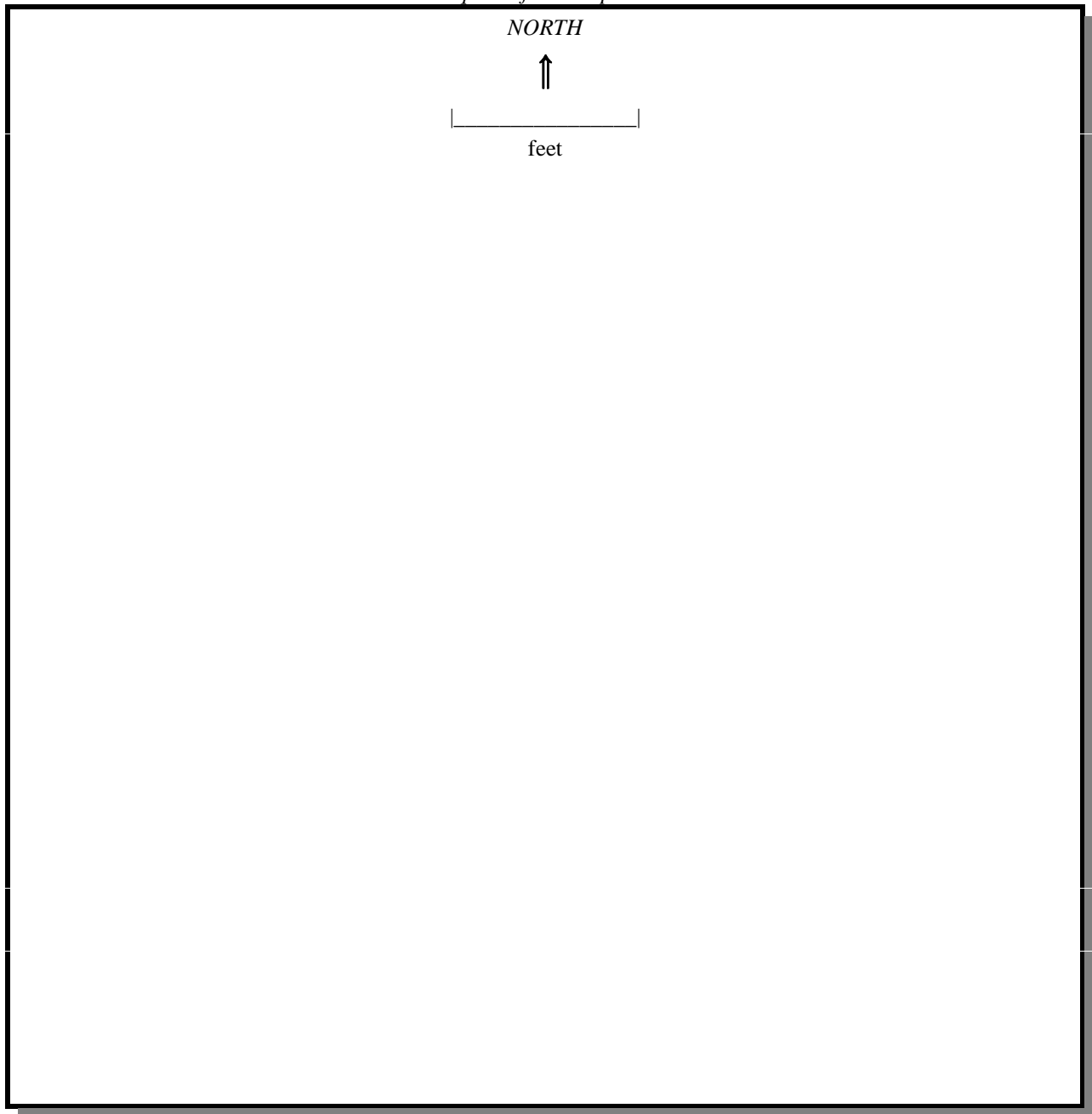
Figure B-1: Site Map^a
Required for All Options



Check each item below to ensure they are included on the site map^a If you generate your own maps, make sure your have plotted all of the following features:

- | | |
|---|--|
| <input type="checkbox"/> Map to scale showing bar scale | <input type="checkbox"/> Monitoring Wells, identification, and locations |
| <input type="checkbox"/> North arrow | <input type="checkbox"/> Sampling locations |
| <input type="checkbox"/> Current and/or former UST systems
(tanks, piping, dispensers; indicate product type for each) | <input type="checkbox"/> Soil stockpiles, treatment areas, other |
| <input type="checkbox"/> Other sources of contamination (ASTs, other) | <input type="checkbox"/> Excavations |
| <input type="checkbox"/> Location of the release, known contamination, and source area | <input type="checkbox"/> Buildings and structures; indicate residential buildings |
| <input type="checkbox"/> Land use of adjacent and nearby properties | <input type="checkbox"/> Utility lines (underground) |
| <input type="checkbox"/> Roads | <input type="checkbox"/> Property lines |
| | <input type="checkbox"/> Geographic land features (surface water, wetlands, other) |

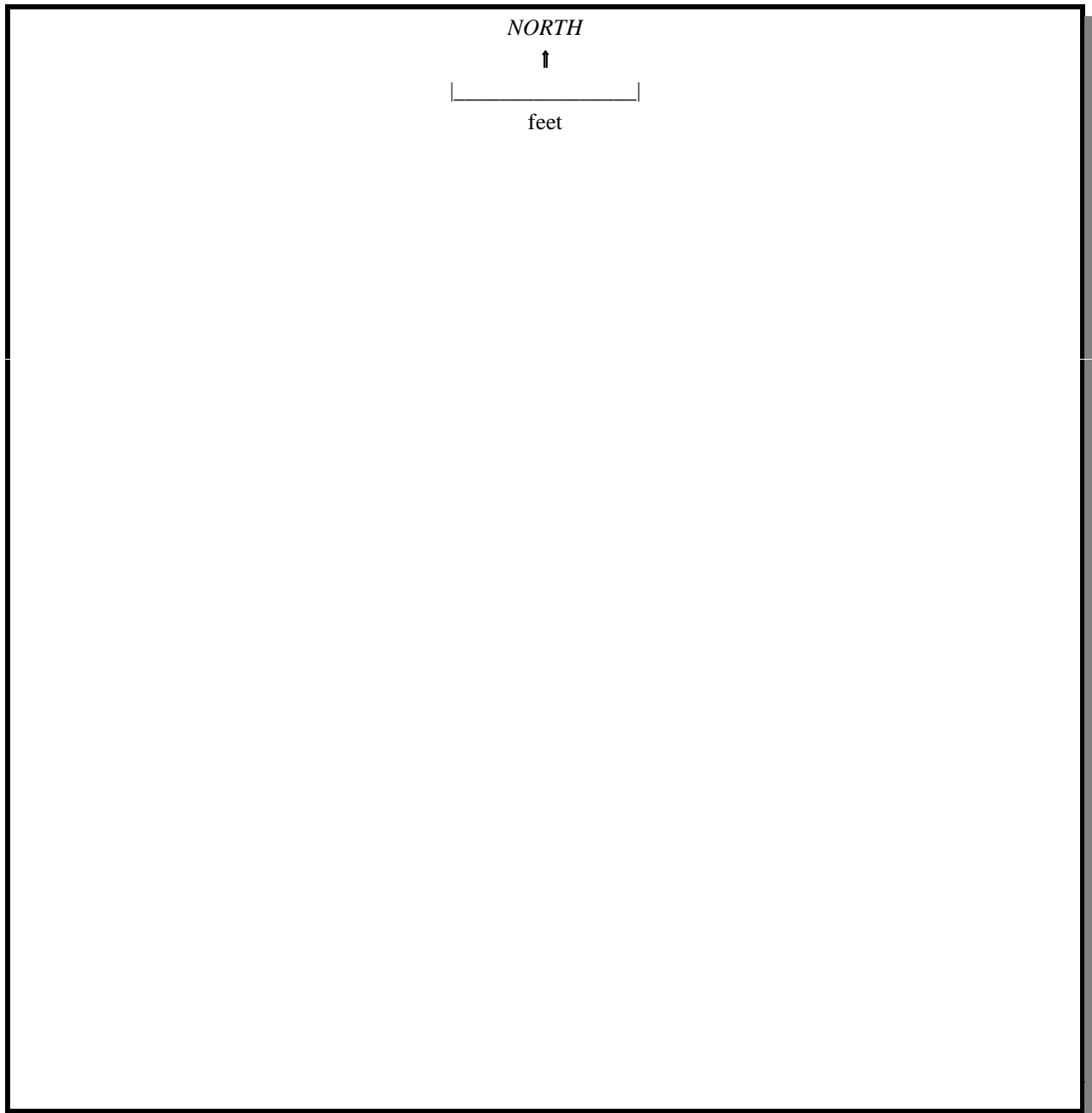
Figure B-2: Vicinity Map
Required for all Options



Check each item below to ensure they are included on the site map. If you generate your own maps, make sure your have plotted all of the following features:

- | | |
|--|---|
| <input type="checkbox"/> Map to scale showing bar scale | <input type="checkbox"/> Roads |
| <input type="checkbox"/> North arrow | <input type="checkbox"/> Utility lines (underground) |
| <input type="checkbox"/> Site location | <input type="checkbox"/> Buildings and structures; indicate residential buildings |
| <input type="checkbox"/> Property lines | <input type="checkbox"/> Excavations |
| <input type="checkbox"/> Monitoring Wells, identification, and locations | <input type="checkbox"/> Sampling locations |
| <input type="checkbox"/> Geographic land features (surface water, wetlands, other) | |
| <input type="checkbox"/> Land use of adjacent and nearby properties | |

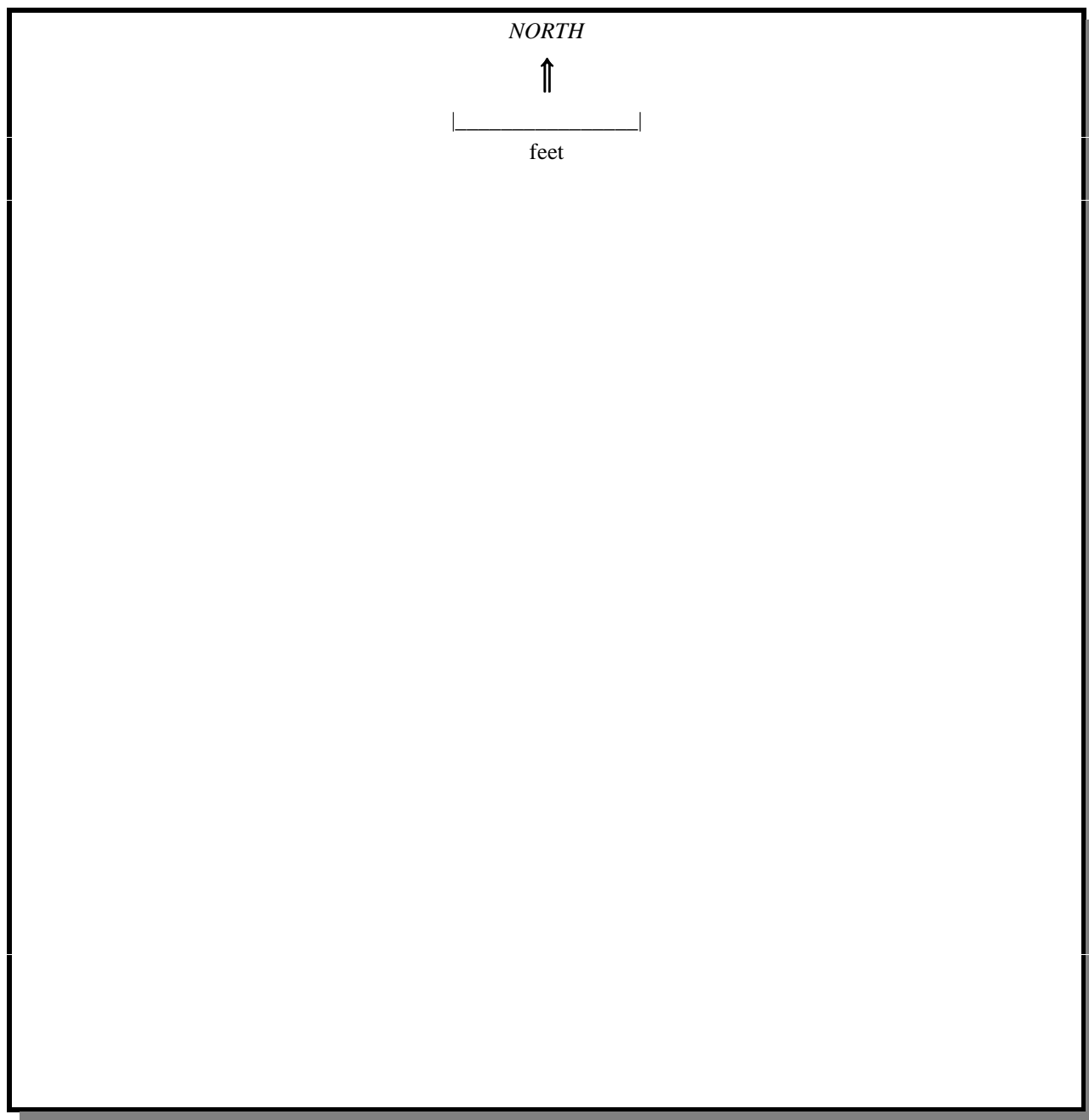
Figure B-3: Groundwater Elevation Maps
Required for Options 2, 3 and 4
(feet above mean sea level or other datum)



Check each item below to ensure they are included on the map . If you generate your own maps, make sure your have plotted all of the following features:

- | | |
|---|---|
| <input type="checkbox"/> Same features as shown on the site and/or vicinity maps | <input type="checkbox"/> Date on which groundwater elevation was measured |
| <input type="checkbox"/> Groundwater elevation measurement in feet above mean sea level for each monitoring point (<i>all wells must be surveyed to a common datum</i>) | <input type="checkbox"/> Contour lines, labeled |

Figure B-4: Contaminant Iso-Concentration Maps
(Prepare Separate Soil and Groundwater Maps)
 Required for Options 2, 3 and 4
 (mg/kg for soil and mg/L for groundwater)

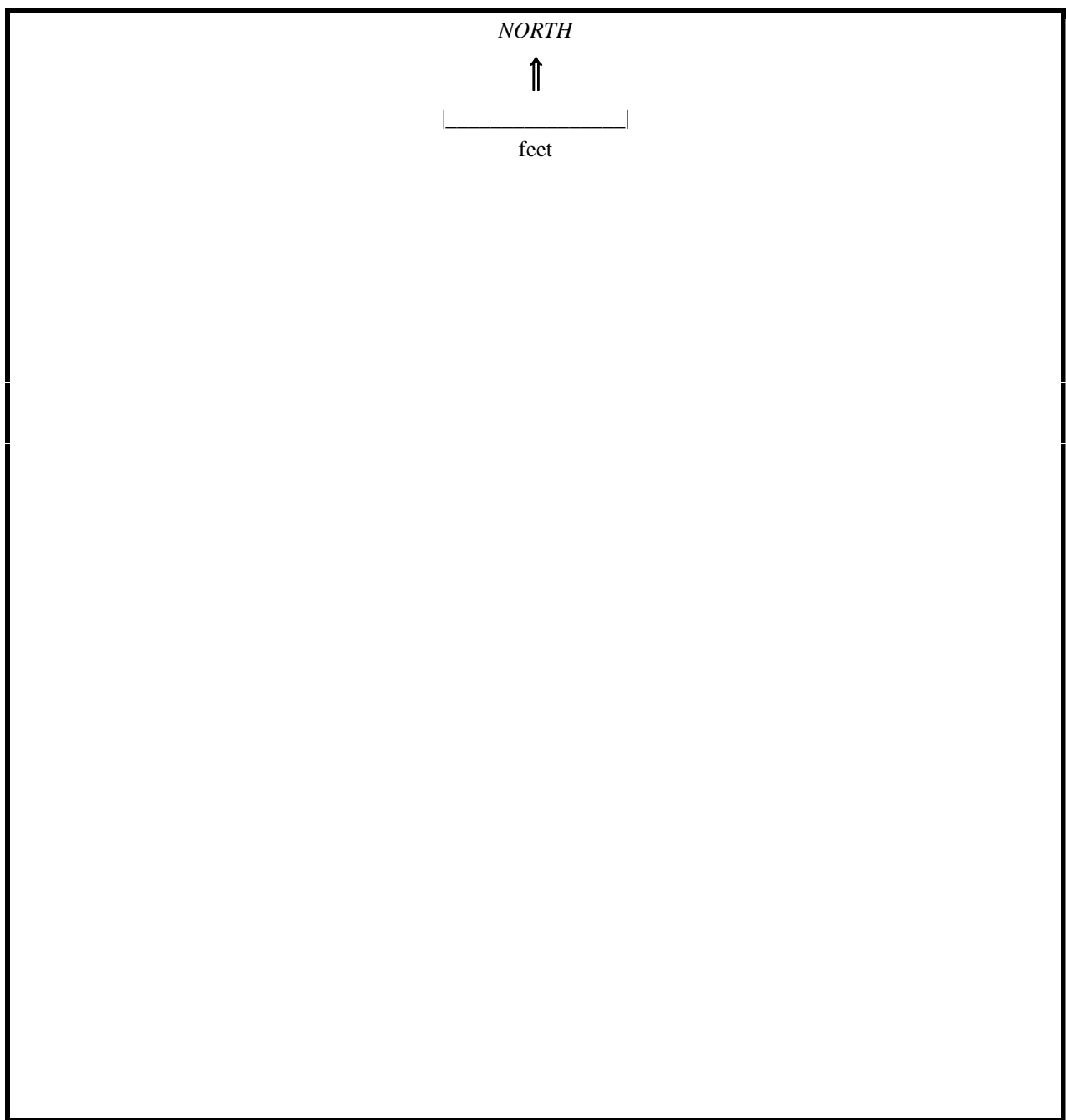


Check each item below to ensure they are included on the site map . If you generate your own maps, make sure your have plotted all of the following features:

- | | |
|---|--|
| <input type="checkbox"/> Same features as shown on the site and/or vicinity maps | <input type="checkbox"/> Date on which samples were collected |
| <input type="checkbox"/> Contaminant concentrations for each monitoring point | <input type="checkbox"/> Contour lines for each contaminant, labeled |
| <input type="checkbox"/> Locations of cross-sections, preferably on soil iso-concentration maps | |

Figure B-5: Electron Acceptor or Metabolic By-Product Iso-Concentration Maps

Required for Options 3 and 4
(mg/L, or other applicable units)



Check each item below to ensure they are included on the site map . If you generate your own maps, make sure your have plotted all of the following features:
(NOTE: One constituent per map)

- ☐ Same features as shown on the site and/or vicinity maps
- ☐ Electron acceptor concentrations for each monitoring point

- ☐ Date on which parameter was measured
- ☐ Contour lines for each parameter, labeled

Figure B-6: Example Graph of Groundwater Elevation, Dissolved Oxygen and Benzene Over Time

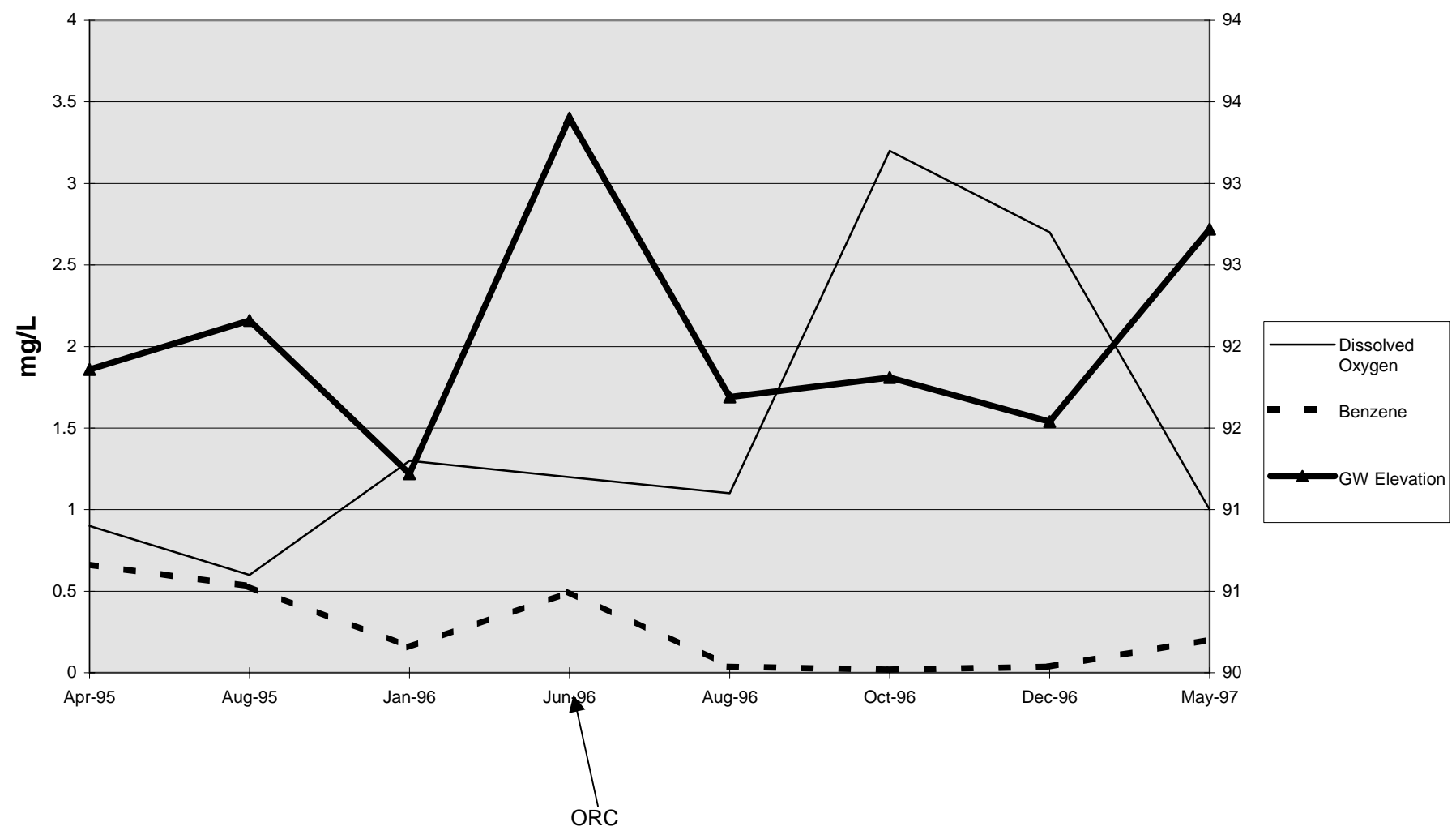


Figure B-7: Example Graph of Groundwater Elevation and Free Product Thickness Over Time

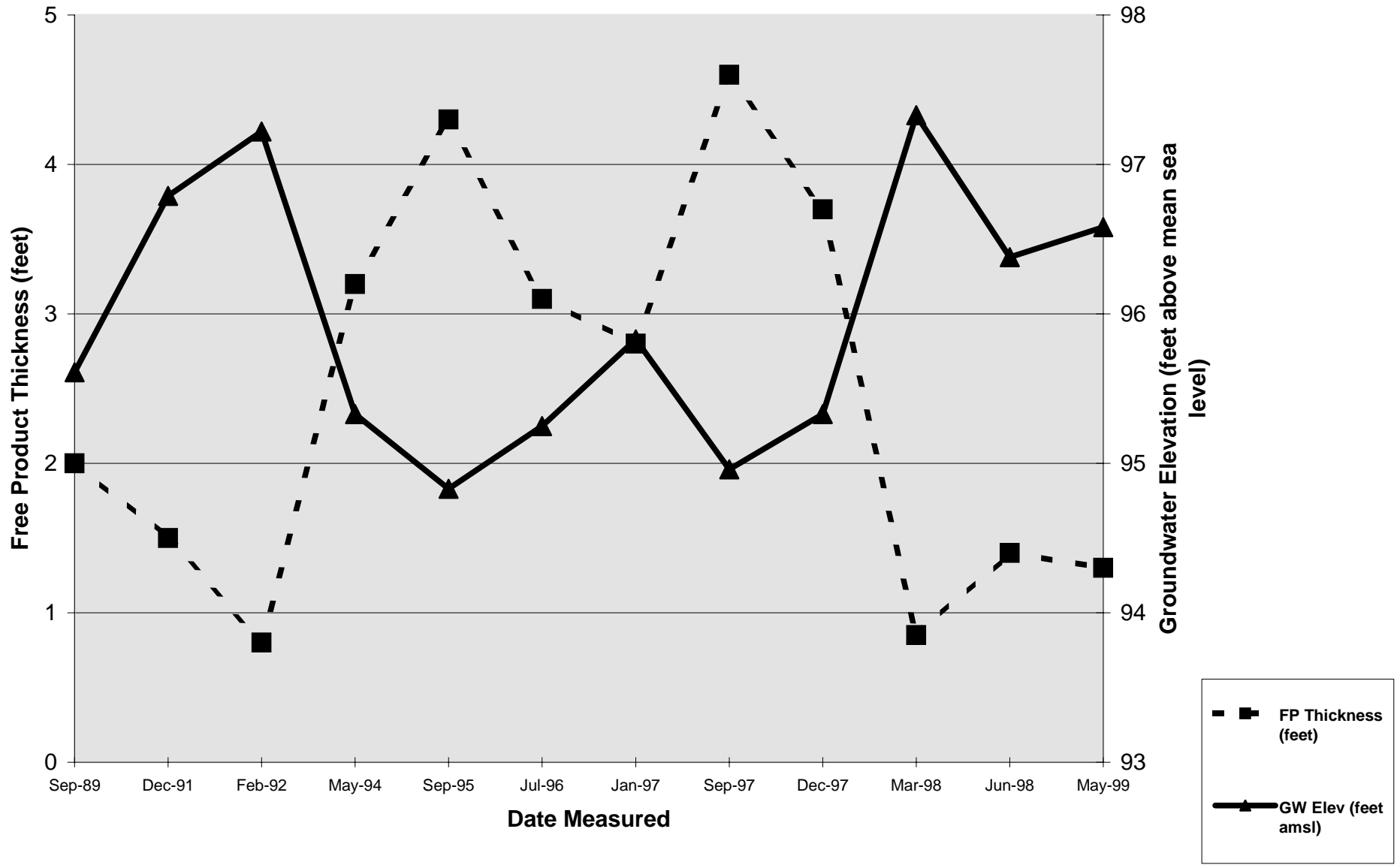


Table B-2

Soil Closure and Confirmation Sample Analytical Results
mg/kg

SAMPLE NAME ^a	Closure	Confir- mation ^b	DEPTH (feet below land surface)	DATE SAMPLE D	BENZENE	TOLUEN E	ETHYL- BENZENE	XYLENES	NAPHTHA- LENE	MTBE	TPH
	<i>check the spaces below that apply</i>	<i>check the spaces below that apply</i>									

^a Sample names must accurately correspond to samples names and locations on the site map.

^b Confirmation samples represent contamination remaining in place.

Table B-3

Groundwater Closure Sample Analytical Results
mg/L

SAMPLE NAME^a	DEPTH to GROUND- WATER (feet below land surface)	DEPTH OF GROUND- WATER SAMPLE (feet below land surface)	DATE SAMPLED	BENZENE	TOLUENE	ETHYL- BENZENE	XYLENES	NAPHTHA- LENE	MTBE	TPH	REMARKS

^a Sample names must accurately correspond to samples names and locations on the site map.

Table B-4

**Groundwater Monitoring Analytical Results
for Contaminants
*mg/L***

SAMPLE NAME^a	DATE SAMPLED	GW Elevation	BENZENE	TOLUENE	ETHYL- BENZENE	XYLENES	NAPHTHA- LENE	MTBE	TPH	REMARKS

Table B-5

**Groundwater Monitoring Analytical Results
for Contaminants and Electron Acceptors
*mg/L***

Sample Name ^a	Date Sampled	GW Elevation	Benzene	Toluene	Ethyl-Benzene	Xylenes	Naphthalene	MTBE	TPH	Dissolved Oxygen	Nitrate	Sulfate	Ferrous Iron

Table B-6: Example of Required Information for Logs of Monitoring Wells, Borings, Drive Points and Test Pits

Depth, feet below land surface	Well Construction Details	Organic Vapor Readings	Blow Counts per foot	Description of Subsurface Soils, Soil Classification
	<ul style="list-style-type: none"> ✓ Traffic protection box ✓ Bentonite seal ✓ Casing ✓ Screened interval ✓ Filter pack ✓ Other 			<p><i>Describe the Below-Listed Features for the Entire Vertical Interval</i></p> <ul style="list-style-type: none"> ✓ Depth to Groundwater ✓ Soil type ✓ Color of soil ✓ Moisture and dryness ✓ Compaction ✓ Organic matter, other debris ✓ Observed contamination ✓ Odors ✓ Other features

Table B-7: Hydraulic Tests: Pump Test and/or Slug Test Data and Results

- ✓ Ensure you have met the requirements shown in the chart below.
- ✓ Attach your raw and resolved field data here.

See Worksheet #2 for Additional Specific Requirements for Hydraulic Tests				
	<i>Option 1</i>	<i>Option 2</i>	<i>Option 3</i>	<i>Option 4</i>
HYDRAULIC CONDUCTIVITY	✓ <u>Optional</u> to perform slug tests at minimum of 2 representative locations	✓ <u>Optional</u> to perform slug tests at minimum of 2 representative locations	✓ <u>Required</u> : Perform slug tests at minimum of 3 representative locations	✓ <u>Required</u> : Perform slug tests at minimum of 4 representative locations <i>or</i> ✓ Perform pumping test at minimum of 1 representative location
OTHER HYDRAULIC TEST FIELD MEASUREMENTS ➤ Transmissivity ➤ Other, (e.g., storage coefficient)	✓ <u>Optional</u> to measure other hydraulic parameters. Check the applicable below: ✓ Transmissivity ✓ Other, specify (e.g., storage coefficient) ✓ _____ ✓ _____ ✓ Other _____ _____ _____	✓ <u>Optional</u> to measure other hydraulic parameters. Check the applicable below: ✓ Transmissivity ✓ Other, specify (e.g., storage coefficient) ✓ _____ ✓ _____ ✓ Other _____ _____ _____	✓ <u>Optional</u> to measure other hydraulic parameters. Check the applicable below: ✓ Transmissivity ✓ Other, specify (e.g., storage coefficient) ✓ _____ ✓ _____ ✓ Other _____ _____ _____	✓ <u>Optional</u> to measure other hydraulic parameters. Check the applicable below: ✓ Transmissivity ✓ Other, specify (e.g., storage coefficient) ✓ _____ ✓ _____ ✓ Other _____ _____ _____

Table B-8: Cross-Section Requirements

Cross-sections, or profiles, aid in determining the extent and degree of contaminant areas relative to receptors. Cross-sections must be drawn to an appropriate horizontal and vertical scale, and include the following features:

- ✓ Two vertical axes with one showing depth in feet below land surface with ground surface being represented by “0 feet,” and the other showing relative elevation so that accurate surface topography is depicted.
- ✓ Location of the water table including a maximum, minimum, and current location with the dates of each properly labeled.
- ✓ Locations of subsurface utility lines.
- ✓ Locations of UST systems.
- ✓ Locations of buildings, streets, highways, surface water bodies, other relevant features and receptors.
- ✓ Locations of borings, probes and monitoring wells to their full depth showing sample intervals, well screen intervals.
- ✓ Sediment type.

APPENDIX C

Calculations for Site-Specific Cleanup Levels (SSCLs)

APPENDIX C

Calculations for Site-Specific Cleanup Levels (SSCLs)

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Exposure and Cross-Media Transport Equations

The exposure and cross-media transport equations provided in this Table C-1 are taken directly from ASTM (1995 and GSI (1995). The equations are tools to manually estimate cleanup levels based on site-specific parameter values. Commercially available electronic spreadsheets may be used in place of the manual equations shown in this section. Whether the equations are solved manually or electronically, the calculated SSCLs and the actual contaminant concentrations must be shown on completed Tables A-1 through A-3 (Appendix A).

Instructions

If manually solving the equations, show your work in the spaces provided or in a similar format. Use the units shown in ASTM, 1995. Use Worksheet #2 (Appendix A) and Table C-2 for the appropriate parameter values required by the equations. ***The parameters values in Table C-2 may not be varied.***

Table C-1

Exposure Medium	Exposure Route	Exposure Equation
C.1.	Air	Inhalation, carcinogens
		$RBSL_{air-c} \frac{ug}{m^3 \text{ air}} = \frac{TER \times BW \times AT_c \times 365days/yr}{SF_i \times IR_{air} \times EF \times ED} \times 10^3 \frac{\mu g}{mg}$
		Inhalation, non-carcinogens
		$RBSL_{air-nc} \frac{ug}{m^3 \text{ air}} = \frac{THQ \times RfD_i \times BW \times AT_{nc} \times 365days/yr}{IR_{air} \times EF \times ED} \times 10^3 \frac{\mu g}{mg}$
C.2.	Groundwater	Ingestion, carcinogens
		$RBSL_{wing-c} \frac{mg}{L \text{ water}} = \frac{TER \times BW \times AT_c \times 365days/yr}{SF_o \times IR_{water} \times EF \times ED}$
		Ingestion, non-carcinogens
		$RBSL_{wing-nc} \frac{mg}{L \text{ water}} = \frac{THQ \times RfD_o \times BW \times AT_{nc} \times 365days/yr}{IR_{water} \times EF \times ED}$

Exposure Medium	Exposure Route	Exposure Equation
C.3.	Groundwater	
	Indoor air (enclosed space) vapor inhalation, <i>carcinogens</i>	$RBSL_{wesp-c} \frac{mg}{L \text{ water}} = \frac{RBSL_{air-c}}{VF_{wesp}} \times 10^{-3} \text{ mg/ug}$
	Indoor air (enclosed space) vapor inhalation, <i>non-carcinogens</i>	$RBSL_{wesp-nc} \frac{mg}{L \text{ water}} = \frac{RBSL_{air-nc}}{VF_{wesp}} \times 10^{-3} \text{ mg/ug}$
C.4.	Groundwater	
	Outdoor air (ambient) vapor inhalation <i>Carcinogens</i>	$RBSL_{wamb-c} \left[\frac{mg}{L} \text{ water} \right] = \frac{RBSL_{air-c}}{VF_{wamb}} \times 10^{-3} \text{ mg/ug}$
	Outdoor air (ambient) vapor inhalation <i>Non-carcinogens</i>	$RBSL_{wamb-nc} \text{ mg/L water} = \frac{RBSL_{air-nc}}{VF_{wamb}} \times 10^{-3} \text{ mg/ug}$

Exposure Medium	Exposure Route	Exposure Equation
C.5. Subsurface Soil	Leaching to groundwater (GW ingestion) <i>Carcinogens</i>	$RBSL_{s-leach, c} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{wing-c}}{LF_{s-w}}$
	Leaching to groundwater (GW ingestion) <i>Non-carcinogens</i>	$RBSL_{s-leach, nc} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{wing-nc}}{LF_{s-w}}$
C.6. Subsurface Soil	Indoor air (enclosed space) vapor inhalation <i>Carcinogens</i>	$RBSL_{seep-c} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{air-c}}{VF_{seep}} \times 10^{-3} \frac{mg}{ug}$
	Indoor air (enclosed space) vapor inhalation <i>Non-carcinogens</i>	$RBSL_{seep-nc} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{air-nc}}{VF_{seep}} \times 10^{-3} \frac{mg}{ug}$
C.7. Subsurface Soil	Outdoor air (ambient) vapor inhalation <i>Carcinogens</i>	$RBSL_{samb-c} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{air-c}}{VF_{samb}} \times 10^{-3} \text{ mg/ug}$
	Outdoor air (ambient) vapor inhalation <i>Non-carcinogens</i>	$RBSL_{samb-nc} \left[\frac{mg}{kg} \text{ soil} \right] = \frac{RBSL_{air-nc}}{VF_{samb}} \times 10^{-3} \text{ mg/ug}$

Exposure Medium	Exposure Route	Exposure Equation
C.8. Surface Soil	Ingestion of soil, inhalation of vapors and particulates, and dermal contact (e.g., excavated soils stockpiles, land farms) <i>Carcinogens</i>	$RBSL_{ss-c} \left[\frac{ug}{kg \text{ soil}} \right] = \frac{TER \times BW \times AT_c \times 365days/yr}{EF \times ED [(SF_o \times 10^{-6} \frac{kg}{mg} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d)) + (SF_i \times IR_{air} \times (VF_{ss} + PEF))]}$
	Ingestion of soil, inhalation of vapors and particulates, and dermal contact (e.g., excavated soils stockpiles, land farms) <i>Non-carcinogens</i>	$RBSL_{ss-nc} \left[\frac{ug}{kg \text{ soil}} \right] = \frac{THQ \times BW \times AT_{nc} \times 365days/yr}{EF \times ED \frac{(10^{-6} \frac{kg}{mg} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d))}{RfD_o} + \frac{(IR_{air} \times (VF_{ss} + PEF))}{RfD_i}}$

Cross-Media Exposure Route and Equations

C.9. VF_{ss} : Surface Soil Volatilization Factor

$$VF_{ss} \left[\frac{(mg/m^3 \text{ air})}{(mg/kg \text{ soil})} \right] = \frac{2W\rho_s}{U_{air}\delta_{air}} \times \sqrt{\frac{D_s^{eff}H}{\pi\tau(\theta_{ws} + k_s\rho_s + H\theta_{as})}} \times 10^3 \frac{cm^3 - kg}{m^3 - g}$$

or

$$VF_{ss} \left[\frac{(mg/m^3 \text{ air})}{(mg/kg \text{ soil})} \right] = \frac{W\rho_s d}{U_{air}\delta_{air}\tau} \times 10^3 \frac{cm^3 - kg}{m^3 - g}$$

whichever is less

C.10. PEF: Particulate Emission Factor

$$PEF \left[\frac{(mg/m^3 \text{ air})}{(mg/kg \text{ soil})} \right] = \frac{P_e W}{U_{air}\delta_{air}} \times 10^3 \frac{cm^3 - kg}{m^3 - g}$$

C.11. VF_{samb} : Subsurface Soil Volatilization to
Outdoor (ambient) Air

$$VF_{samb} \left[\frac{(mg/m^3 \text{ air})}{(mg/kg \text{ soil})} \right] = \frac{H\rho_s}{[\theta_{ws} + k_s\rho_s + H\theta_{as}] \left[1 + \frac{U_{air}\delta_{air}L_s}{D_s^{eff}W} \right]} \times 10^3 \frac{cm^3 - g}{m^3 - g}$$

C.12. VF_{seps} : Subsurface Soil Volatilization to Enclosed Space (indoor air)

$$VF_{seps} \left[\frac{(mg/m^3 \text{ air})}{(mg/kg \text{ soil})} \right] = \frac{\frac{H\rho_s}{[\theta_{ws} + k_s\rho_s + H\theta_{as}]} \left[\frac{D_s^{eff} / L_s}{ER L_B} \right]}{1 + \left[\frac{D_s^{eff}/L_s}{ER L_B} \right] + \left[\frac{D_s^{eff}/L_s}{(D_{crack}^{eff}/L_{crack})\eta} \right]} \times 10^3 \frac{cm^3 - kg}{m^3 - kg}$$

C.13. VF_{wamb} : Groundwater Volatilization Factor to Outdoor (ambient) Air

$$VF_{wamb} \left[\frac{(mg/m^3 \text{ air})}{(mg/L \text{ water})} \right] = \frac{H}{1 + \left[\frac{U_{air}\delta_{air}L_{GW}}{WD_{ws}^{eff}} \right]} \times 10^3 \frac{L}{m^3}$$

C.14. VF_{wesp} : Groundwater Volatilization Factor to Indoor Air (enclosed space)

$$VF_{wesp} \left[\frac{mg/m^3 \text{ air}}{mg/L \text{ water}} \right] = \frac{H \left[\frac{D_{ws}^{eff} / L_{GW}}{ER L_B} \right]}{1 + \left[\frac{D_{ws}^{eff} / L_{GW}}{ER L_B} \right] + \left[\frac{D_{ws}^{eff} / L_{GW}}{(D_{crack}^{eff} / L_{crack}) \eta} \right]} \times 10^3 L/m^3$$

Cross-Media Exposure Route and Equations

C.15. K_{sw} : Soil Leachate Partition Factor

$$K_{s-w} \left[\frac{\text{mg/L-water}}{\text{mg/kg-soil}} \right] = \frac{\rho_s}{\theta_{ws} + (Kd \times \rho_s) + (H \times \theta_{as})}$$

C.16. LDF: Soil Leachate-Groundwater Dilution Factor

$$LDF \text{ (dimensionless)} = 1 + \frac{U_{darcy} \times \delta_{gw}}{I \times W}$$

or use C.17 below

C.17. LF_{sw} : Leaching Factor, soil to groundwater

$$LF_{s-w} \frac{\text{mg/L-water}}{\text{mg/kg-soil}} = \frac{\rho_s}{(\theta_{ws} + (Kd \times \rho_s) + (H \times \theta_{as})) \times \left(1 + \frac{U_{darcy} \times \delta_{gw}}{I \times W} \right)}$$

C.18. D_s^{eff} : Effective Diffusivity in Vadose Zone Soils

$$D_s^{eff} \left[\frac{\text{cm}^2}{\text{sec}} \right] = D_{air} \frac{\theta_{as}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H} \right] \left[\frac{\theta_{ws}^{3.33}}{\theta_T^2} \right]$$

Cross-Media Exposure Route and Equations

C.19. D_{ws}^{eff} : Effective Diffusivity above the Water Table

$$D_{ws}^{eff} \left[\frac{cm^2}{sec} \right] = (h_{capf} + h_v) \left[\frac{h_{capf}}{D_{capf}^{eff}} + \frac{h_v}{D_s^{eff}} \right]^{-1}$$

C.20. D_{crack}^{eff} : Effective Diffusivity through Foundations Cracks

$$D_{crack}^{eff} \left[\frac{cm^2}{sec} \right] = D_{air} \frac{\theta_{crack}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H} \right] \left[\frac{\theta_{wcrack}^{3.33}}{\theta_T^2} \right]$$

C.21. D_{wcap}^{eff} : Effective Diffusivity through the Capillary Fringe

$$D_{capf}^{eff} \left[\frac{cm^2}{sec} \right] = D_{air} \frac{\theta_{acap}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H} \right] \left[\frac{\theta_{wcap}^{3.33}}{\theta_T^2} \right]$$

Equations for Solving Lateral Groundwater Dilution Attenuation Factor

C.22. Solute Transport with First-Order Decay

$$\frac{C_{(x)i}}{C_{si}} = \exp \left(\frac{x}{2\alpha_x} \left[1 - \sqrt{1 + \frac{4\lambda_i \alpha_x R_i}{U_{tran}}} \right] \right) \operatorname{erf} \left(\frac{S_w}{4\sqrt{\alpha_y x}} \right) \operatorname{erf} \left(\frac{S_d}{2\sqrt{\alpha_z x}} \right)$$

$$DAF = \frac{C_{si}}{C_{(x)i}}$$

Parameters shown below are not in Worksheet #2

$C_{(x)i}$	Concentration of constituent i at distance x
C_{si}	Concentration of constituent i in source zone
S_d	Source depth (cm)
S_w	Source width (cm)
erf	Complementary error function.
x	Distance down-gradient of source (cm)
λ_i	First-order degradation rate (day^{-1}) for constituent i

C.23. Solute Transport with Biodegradation by Electron Acceptor Superposition Model

$$C_{(x)i} = \left[C_{si} + BC_i \right] \operatorname{erf} \left(\frac{S_w}{4\sqrt{\alpha_y x}} \right) \operatorname{erf} \left(\frac{S_d}{4\sqrt{\alpha_z x}} \right) - BC_i$$

$$BC_i = BC_T \frac{C_{si}}{\sum C_{si}}$$

$$BC_T = \sum \frac{C(ea)_n}{UF_n}$$

$$NAF = \frac{C_{si}}{C_{(x)i}}$$

Parameters shown below are not in Worksheet #2

NAF	Natural Attenuation Factor, or Dilution-Attenuation Factor (DAF)
-----	--

C. 24. Lateral Air Dispersion Factor

$$\frac{C(x)_i}{C_{si}} = \frac{Q}{2\pi U_{air} \sigma_y \sigma_z} \times \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left(\exp\left(-\frac{(z - \delta_{air})^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + \delta_{air})^2}{2\sigma_z^2}\right) \right)$$

$$Q = \frac{U_{air} (\delta_{air}) (A)}{L}$$

Air Dispersion Factor (ADF)

$$ADF = \frac{C_{si}}{C_{(x)i}}$$

Cross-Media Exposure Route and Equations

C.25. Natural Attenuation Factor (NAF), field-measured empirical method:

$$NAF = \frac{\text{contaminant concentration at source}}{\text{contaminant concentration at down-gradient receptor, sampling point}}$$

C.26. Groundwater Seepage/Transport Velocity (U_{tran}):

$$U_{tran} = \frac{K i}{\theta_{eff}}$$

C.27. Contaminant Retardation (R): *(Calculate only if you have reliable data for the input parameters)*

$$R = 1 + \frac{\rho_s}{\theta_{eff}} \times (Koc \times foc)$$

C.28. Contaminant Velocity (C_v):

(Use groundwater velocity if retardation parameters are uncertain or highly variable)

$$C_v = \frac{U_{tran}}{R}$$

C.29. Distribution/Partitioning Coefficient (K_d) (for organic chemicals only)

$$K_d = Koc \times foc$$

Calculating Site-Specific Cleanup Levels

C.30. Site-Specific Cleanup Levels (SSCLs)

$$SSCL_i = RBSL_i \times NAF$$

NAF = Natural Attenuation Factor, unitless (see equation C.25 above). The NAF may be derived empirically from field data or derived from modeling, if applicable. The NAF may include the ADF for wind-born contamination (equation C.24) and the DAF for contaminants dissolved in groundwater (equations C.22 and C.23).

Table C-2: TPH Fraction-Specific ^a and Chemical-Specific Property ^a and Toxicity Values

TPH Fractions and Chemicals showing Carbon Number and Representative CAS number	EPA Analytical Method ^b	Molecular Weight (g/mol)	Vapor Pressure ^c (mm Hg)	Henry's Law Constant ^d (L-H ₂ O/L-air, unitless)	Diffusion Coefficient in Air ^e (D ^{air} , cm ² /s)	Diffusion Coefficient in Water ^e (D ^w , cm ² /s)	Aqueous Solubility (20-25° C) (pure compound) (mg/L)	Adsorption Coefficient (K _{oc}) (mL/g)	Cancer Slope Factor, Oral (SF _o) (kg-day/mg)	Cancer Slope Factor, Inhalation (SF _i) (kg-day/mg)	Reference Dose, Oral (RfD _o) (mg/kg-day)	Reference Dose, Inhalation ^f (RfD _i) (mg/kg-day)
ALIPHATICS												
C₅ - C₆ 110-54-3	8260B81		2.66 E+02 ^g	4.10 E+01	8.57 E-02	8.34 E-06	3.60 E+01	6.31 E+02	-	-	6.00 E-02 ^h	6.00 E-02 ^h
C₇ - C₈ 142-82-5	8260B100		4.80 E+01	7.70 E+01	6.69 E-02	6.89 E-06	5.40 E+00	3.16 E+03	-	-	6.00 E-02 ^h	6.00 E-02 ^h
C₉ - C₁₀ 111-84-2	8260B130		5.00 E+00	1.60 E+02	6.44 E-02	5.90 E-06	4.30 E-01	3.16 E+04	-	-	1.00 E-01 ⁱ	2.90 E-01 ⁱ
C₁₁ - C₁₂ 1120-21-4	8270B160		4.80 E-01	1.60 E+02	4.60 E-02	5.19 E-06	3.40 E-02	3.16 E+05	-	-	1.00 E-01 ⁱ	2.90 E-01 ⁱ
C₁₃ - C₁₆ 544-76-3	8270B200		3.60 E-02	1.60 E+02	3.95 E-02	4.50 E-06	7.60 E-04	5.00 E+06	-	-	1.00 E-01 ⁱ	2.90 E-01 ⁱ
C₁₇ - C₂₁ 544-76-3	8270B270		8.40 E-04	1.10 E+02	3.28 E-02	3.76 E-06	2.50 E-06	4.00 E+08	-	-	2.00 E+00 ⁱ	na ⁱ
C₂₂ - C₃₅ 629-78-7	8270B280		8.40 E-04	1.10 E+02	3.28 E-02	3.76 E-06	1.50 E-06	4.00 E+08	-	-	2.00 E+00 ⁱ	na ⁱ

Table C-2: TPH Fraction-Specific ^a and Chemical-Specific Property ^a and Toxicity Values

TPH Fractions and Chemicals showing Carbon Number and Representative CAS number	EPA Analytical Method ^b	Molecular Weight (g/mol)	Vapor Pressure ^c (mm Hg)	Henry's Law Constant ^d (L-H ₂ O/L-air, unitless)	Diffusion Coefficient in Air ^e (D ^{air} , cm ² /s)	Diffusion Coefficient in Water ^e (D ^w , cm ² /s)	Aqueous Solubility (20-25° C) (pure compound) (mg/L)	Adsorption Coefficient (K _{oc}) (mL/g)	Cancer Slope Factor, Oral (SF _o) (kg-day/mg)	Cancer Slope Factor, Inhalation (SF _i) (kg-day/mg)	Reference Dose, Oral (RfD _o) (mg/kg-day)	Reference Dose, Inhalation ^f (RfD _i) (mg/kg-day)
AROMATICS												
Benzene C₆ 71-43-2	8260B7	78.11	9.50 E+01	2.25 E-01	8.80 E-02	9.80 E-06	1.78 E+03	8.12 E+01	2.90 E-02 ^j	2.90 E-02 ^j	-	-
Toluene C₇ 108-88-3	8260B9	92.13	2.85 E+01	2.74 E-01	8.57 E-02	8.60 E-06	5.15 E+02	2.34 E+02	-	-	2.00 E-01 ^j	1.10 E-01 ^j
Ethylbenzene C₈ 100-41-4	8260B10	106.2	9.50 E+00	3.58 E-01	7.50 E-02	7.80 E-06	1.52 E+02	5.37 E+02	-	-	1.00 E-01 ^j	2.90 E-01 ^j
Xylenes C₈ 1330-20-7 ¹	8260B10	106.2	8.59 E+00	2.52 E-01	7.85 E-02	8.90 E-06	1.98 E+02	5.86 E+02	-	-	2.00 E+00 ^j	2.00 E+00 ^j
Naphthalene C₁₀ 91-20-3	8260B12	128.19	2.76 E-01	1.74 E-02	5.90 E-02	7.50 E-06	3.10 E+01	8.44 E+02	-	-	2.00 E-02 ^k	8.60 E-04 ^k
Methyl t-Butyl Ether (MtBE) 1634-04-4 ^m	8260B88	88.146	2.49 E+02	2.40 E-02	7.92 E-02	9.41 E-05	4.30 E+04	1.20 E+01	-	-	5.00 E-03 ^o	8.57 E-01 ^k
C₉ - C₁₀ (alkyl benzenes) 108-67-8	8260B120	120.2 - 134.22	5.00 E+00	4.20 E-01	6.00 E-02	7.51 E-06	1.10 E+02	1.26 E+03	-	-	4.00 E-02 ⁱ	6.00 E-02 ⁱ
C₁₁ - C₁₃ (total alkyl naphthalenes) ⁿ 90-12--0	8270B142	142.2 - 176.2	5.00 E-02	2.30 E-02	4.80 E-02	7.67 E-06	1.45 E+03	7.06 E+03	-	-	4.00 E-02 ⁱ	6.00 E-02 ⁱ
C₁₂ - C₂₂ ^p (polynuclear aromatic hydrocarbons) 56-55-3	8270B152	152.2 - 278.35	2.70 E-03	4.12 E-01	3.23 E-02	1.66 E-05	4.86 E+01	6.29 E+04	-	-	3.00 E-02 ⁱ	na ⁱ

Table C-2: TPH Fraction-Specific ^a and Chemical-Specific Property ^a and Toxicity Values

TPH Fractions and Chemicals showing Carbon Number and Representative CAS number	EPA Analytical Method ^b	Molecular Weight (g/mol)	Vapor Pressure ^c (mm Hg)	Henry's Law Constant ^d (L-H ₂ O/L-air, unitless)	Diffusion Coefficient in Air ^e (D ^{air} , cm ² /s)	Diffusion Coefficient in Water ^e (D ^w , cm ² /s)	Aqueous Solubility (20-25° C) (pure compound) (mg/L)	Adsorption Coefficient (K _{oc}) (mL/g)	Cancer Slope Factor, Oral (SF _o) (kg-day/mg)	Cancer Slope Factor, Inhalation (SF _i) (kg-day/mg)	Reference Dose, Oral (RfD _o) (mg/kg-day)	Reference Dose, Inhalation ^f (RfD _i) (mg/kg-day)
POLYNUCLEAR AROMATIC HYDROCARBONS (PAHs)												
Acenaphthylene C₁₂ 208-96-8	8270B1	152.2	3.11 E-02	3.39 E-03	4.40 E-02	7.53 E-06	1.61 E+01	2.77 E+03	-	-	3.00 E-02 ^q	na
Acenaphthene C₁₂ 83-32-9	8270B1	154.21	1.14 E-02	4.91 E-03	4.21 E-02	7.69 E-06	3.80 E+00	2.38 E+03	-	-	6.00 E-02 ^j	1.70 E-02 ⁱ
Fluorene C₁₃ 86-73-7	8270B1	166.2	5.37 E-03	3.19 E-03	3.60 E-02	7.88 E-06	1.90 E+00	3.90 E+03	-	-	4.00 E-02 ^j	1.10 E-02 ⁱ
Phenanthrene C₁₄ 85-01-8	8270B1	178.2	8.51 E-04	1.31 E-03	3.30 E-02	7.47 E-06	1.10 E+00	8.14 E+03	-	-	3.00 E-02 ^q	na
Anthracene C₁₄ 120-12-7	8270B1	178.2	5.84 E-04	1.60 E-03	3.24 E-02	7.74 E-06	4.50 E-02	7.69 E+03	-	-	3.00 E-01 ^j	8.57 E-02 ⁱ
Fluoranthene C₁₆ 206-44-0	8270B2	202.3	6.54 E-05	4.17 E-04	3.02 E-02	6.35 E-06	2.60 E-01	2.78 E+04	-	-	4.00 E-02 ^j	1.14 E-02 ⁱ
Pyrene C₁₆ 129-00-0	8270B2	202.3	8.89 E-05	3.71 E-04	2.70 E-02	7.24 E-06	1.32 E-01	2.57 E+04	-	-	3.00 E-02 ^j	8.57 E-03 ⁱ
Benz(a)-Anthracene C₁₈ 56-55-3	8270B2	228.3	4.54 E-06	2.34 E-04	5.10 E-02	9.00 E-06	1.10 E-01	1.02 E+05	7.30 E-01 ⁱ	7.30 E-02 ⁱ	-	-

Table C-2: TPH Fraction-Specific ^a and Chemical-Specific ^a Property and Toxicity Values

TPH Fractions and Chemicals showing Carbon Number and Representative CAS number	EPA Analytical Method ^b	Molecular Weight (g/mol)	Vapor Pressure ^c (mm Hg)	Henry's Law Constant ^d (L-H ₂ O/ L-air, unitless)	Diffusion Coefficient in Air ^e (D ^{air} , cm ² /s)	Diffusion Coefficient in Water ^e (D ^w , cm ² /s)	Aqueous Solubility (20-25° C) (pure compound) (mg/L)	Adsorption Coefficient (Koc) (mL/g)	Cancer Slope Factor, Oral (SF _o) (kg-day/mg)	Cancer Slope Factor, Inhalation (SF _i) (kg-day/mg)	Reference Dose, Oral (RfD _o) (mg/kg-day)	Reference Dose, Inhalation ^f (RfD _i) (mg/kg-day)
POLYNUCLEAR AROMATIC HYDROCARBONS (PAHs), continued												
Chrysene C ₁₈ 218-01-9	8270B	228.3	8.06 E-07	1.80 E-04	2.48 E-02	6.21 E-06	1.50 E-03	8.14 E+04	7.30 E-03 ⁱ	7.30 E-03 ⁱ	-	-
Benzo(b)-Fluoranthene C ₂₀ 205-99-2	8270B	252.32	5.07 E-05	8.36 E-04	2.26 E-02	5.56 E-06	1.50 E-03	8.30 E+04	7.30 E-01 ⁱ	7.30 E-01 ⁱ	-	-
Benzo(k)-Fluoranthene C ₂₀ 207-08-9	8270B	252.32	3.09 E-08	6.46 E-06	2.26 E-02	5.56 E-06	8.00 E-04	1.21 E+05	7.30 E-02 ⁱ	7.30 E-02 ⁱ	-	-
Benzo(a)-Pyrene C ₂₀ 50-32-8	8270B	252.3	1.60 E-07	1.86 E-05	4.30 E-02	9.00 E-06	3.80 E-03	1.31 E+05	7.30E+00 ^m	6.10E+00 ^m	-	-
Indeno(1, 2, 3-Cd) Pyrene C ₂₂ 193-39-5	8270B	276.34	7.60 E-07	2.07 E-11	2.30 E-02	4.41 E-06	6.20 E-02	8.00 E+05	7.30 E-01 ^o	6.10 E-01 ^o	-	-
Dibenzo-(a, h) Anthracene C ₂₂ 53-70-3	8270B	278.35	5.20 E-10	1.58 E-05	2.00 E-02	5.24 E-06	5.00 E-04	7.41 E+05	7.30 E-01 ^o	6.10 E-01 ^o	-	-
Benzo(g, h, i)-Perylene C ₂₀ 191-24-2	8270B	268.36	1.69 E-07	3.03 E-05	4.90 E-02	5.56 E-06	3.00 E-04	3.11 E+05	-	-	3.00 E-02 ^q	na ^q

Notes: - not applicable
na not available

a after Gustafson, et. al., 1997, Tables 3, 7 and 8.

b The EPA laboratory methods listed only pertain to the TPH fractionation process. Note that MTBE/BTEXN are also analyzed and reported when using EPA method 8260B for the TPH fractionation.

c mm Hg = 760 X atmospheres

d Henry's Law Constant (H) unit conversion:

$$\frac{H \text{ unitless}}{41.6} = \frac{H \text{ atmospheres} \cdot \text{meter}^3}{\text{mole}}$$

e Diffusion coefficients for the TPH fractions are based on averages shown in Gustafson, et al., 1997, Table 3.

f Conversion formula for converting Reference Concentration (RfC) mg/m³ to Reference Dose-inhalation (RfD_i) mg/kg-day:

$$RfC \frac{\text{mg}}{\text{m}^3} \times \frac{1}{70 \text{ kg body weight}} \times \frac{20 \text{ m}^3}{\text{day}} \text{ breathing rate} = RfD_i \frac{\text{mg}}{\text{kg-day}}$$

g E = Exponent to the base 10; for example, 7.45 E-05 = 7.45 X 10⁻⁵ = 0.0000745

h Hexane RfD and RfC based on USEPA (HEAST), 1997.

i after Edwards, et al., 1997.

j USEPA (IRIS), 1998a.

k USEPA (IRIS), 1998b.

l Total xylenes parameter values are based on average values of ortho-xylene, para-xylene and meta-xylene. ASTM, 1997.

n C₁₁ - C₁₃ alkyl (or methyl) naphthalenes include the following chemicals. Fate and transport properties for this fraction are based on average values:

2-Methyl-naphthalene C₁₁
1-Methyl-naphthalene C₁₁
Total Dimethyl Naphthalenes C₁₂
Total Trimethyl Naphthalenes C₁₃

o USEPA Region 3 Risk-Based Concentration table, EPA Region 3, March 1995.

p C₁₂ - C₂₂ polynuclear aromatic hydrocarbons include the following chemicals. Fate and transport properties for this fraction are based on average values:

Acenaphthylene	C ₁₂
Acenaphthene	C ₁₂
Fluorene	C ₁₃
Phenanthrene	C ₁₄
Anthracene	C ₁₄
Fluoranthene	C ₁₆
Pyrene	C ₁₆
* Benz(a)-Anthracene	C ₁₈
* Chrysene	C ₁₈
* Benzo(b)-Fluoranthene	C ₂₀
* Benzo(k)-Fluoranthene	C ₂₀
* Benzo(a)-Pyrene	C ₂₀
* Indeno(1,2,3-Cd)Pyrene	C ₂₂
* Dibenzo(a,h)Anthracene	C ₂₂
Benzo(g,h,i)Perylene	C ₂₂

* = Carcinogenic compounds. If these compounds are detected, SSCLs must be calculated for those compounds using their unique chemical and toxicity parameter values.

q no toxicity data available; values used are for the C₁₇ to C₃₅ aromatic fraction according to Edwards, et al., 1997.

Table C-3: Determination of RBSL and SSCL Values for Total Petroleum Hydrocarbons (TPH)

1.	Sample Collection
•	Collect a minimum of one environmental sample which is representative of each contaminated medium (e.g., soil and groundwater) and the maximum concentration and composition of the petroleum contamination at the site. For sites where TPH contamination is highly variable in concentration or composition, the user should collect multiple TPH samples at representative locations to ensure a representative analysis by the laboratory.
2.	Laboratory Analysis
•	Analyze the sample(s) using EPA methods 8260B and 8270B. Specify “Utah TPH Fractionation” on your chain of custody forms to ensure that the laboratory uses the reporting format specific for TPH fractionation which differs from a typical 8260B and/or 8270B chemical parameter listing. The laboratory should report concentrations for each of the 10 different TPH fractions listed in Table C-2. In addition, on the 8260B report, the laboratory should list values for any detectable BTEXN and MTBE. For fractions where the measured concentration is below the method reporting limit, a value of half the method reporting limit should be used as the representative source area concentration in deriving SSCLs.
3.	Determination of Tier 2 RBSLs for Each TPH Fraction
•	Fraction-specific RBSL values must be derived for each complete exposure pathway at the site. For each TPH fraction, RBSL values can be calculated for each relevant exposure pathway using the equations provided on Table C-1 (see Equations C.1 through C.8). Fraction-specific chemical property values and toxicological parameters to be used in the RBSL calculations are provided in Table C-2.
4.	Determination of SSCL Values for TPH Fractions
•	Under Tier 2 Options 2 through 4, SSCL values for the individual TPH fractions are developed in the same manner as for any other COCs (e.g., BTEXN and MTBE). Using the chemical property values and toxicological parameter values listed on Table C-2, a NAF value may be derived for each TPH fraction using the Option 2 through 4 calculation methods. The NAF is then multiplied by the appropriate RBSL value to obtain an SSCL for each complete exposure pathway. The fraction that exceeds its applicable SSCL the most will ultimately drive the cleanup for all the other fractions contained within TPH at the site.
5.	Confirmation Sampling for TPH Fractions Following TPH-Driven Cleanup Activities
•	After completing cleanup activities that are driven by the exceedence of SSCLs for the TPH fraction(s), the user should obtain an appropriate number of environmental samples at representative locations and depths in order to verify the effectiveness of the cleanup at the release site. The same procedures described herein would again be employed for comparison with representative source area TPH fractionation values obtained. During cleanup, the user may elect to obtain samples for TPH fractionation, and BTEXN and MTBE (8260B method) if applicable, to measure the relative progress of the cleanup activities and to estimate the cleanup duration.

Figure C-1: Procedures for Locating Alternate Monitoring Points (AMPs) and Calculating Action Levels (ALs)

The following figures show how locations for groundwater Alternate Monitoring Points (AMPs) and the corresponding Action Levels (ALs) for the AMPs are calculated. The location in which to place a AMPs for monitoring groundwater trends directly down-gradient of the source and along a plume's centerline can be calculated based on a contaminant's velocity, distance the contaminant travels in one year, and the distance between the source area to the Point of Exposure (POE).

The one year time frame is suggested for most sites that have been monitored quarterly, but may be varied based on site-specific conditions. A one year travel time is simply a starting point to determine if an AMP AL, and the RBSL at the POE, might be exceeded. If the calculations for locating AMPs show the locations to be beyond the POE, then more accurate contaminant velocity and travel time data must be obtained, and/or more data regarding concentrations at the POE must be obtained. Regardless, the travel time used in the calculations must be capable of providing sufficient response time to protect the POE.

The example shown below illustrates the steps for calculating locations of AMPs and calculating ALs. The example shows a groundwater contaminant source area 200 feet up-gradient from a receptor.

Step 1: Calculate Location of an Alternate Monitoring Point: Determine the minimum distance that a contaminant travels in one year using groundwater velocity data and the example figures and example site properties.

- a. Determine the groundwater transport velocity based on example site properties, as follows:

$$GW \text{ transport velocity } \frac{\text{feet}}{\text{day}} = \frac{K \times i}{\theta_{eff}}$$

EXAMPLE

$$GW \text{ transport velocity} = \frac{\frac{5 \text{ ft}}{\text{day}} \times \frac{0.02 \text{ ft}}{\text{ft}}}{0.2} = 0.5 \frac{\text{ft}}{\text{day}}$$

- b. Determine Contaminant velocity

$$\text{Contaminant (benzene) transport velocity } \frac{\text{feet}}{\text{day}} = \frac{GW \text{ transport velocity}}{Rf}$$

Rf = Retardation factor, unitless

$$\text{Retardation factor} = 1 + \left(\frac{\rho_s}{\theta_{eff}} \times Kd \right)$$

**Figure C-1: Procedures for Locating Alternate Monitoring Points (AMPs) and Calculating Action Levels (ALs),
continued**

step 1, *continued*

EXAMPLE

$$Kd = Koc \times foc_{sat} = 50 \text{ mL/g} \times 0.001 = 0.05 \text{ mL/g}$$

$$Retardation \text{ factor} = 1 + \left(\frac{1.7 \frac{g}{cm^3}}{0.2} \times 0.05 \frac{mL}{g} \right) = 1.43$$

$$Benzene \text{ transport velocity} = \frac{0.5ft}{1.43} = 0.35 \frac{ft}{day}$$

- c. Solve for distance traveled in 1 year from the up-gradient AMP to the down-gradient POE, as follows:

EXAMPLE

$$Distance = Travel \text{ Time} \times Benzene \text{ transport velocity} = 365 \text{ days} \times \frac{0.35 \text{ ft}}{day} = 127 \text{ feet}$$

Step 2: Calculate ALs for the groundwater AMPs. Solve the exposure and cross-media transport equations in the same way that SSCLs for the source were calculated except the distance entered in the equations will be the distance from the newly placed AMP to the receptor. In the case of this example, that distance would be 127 feet.

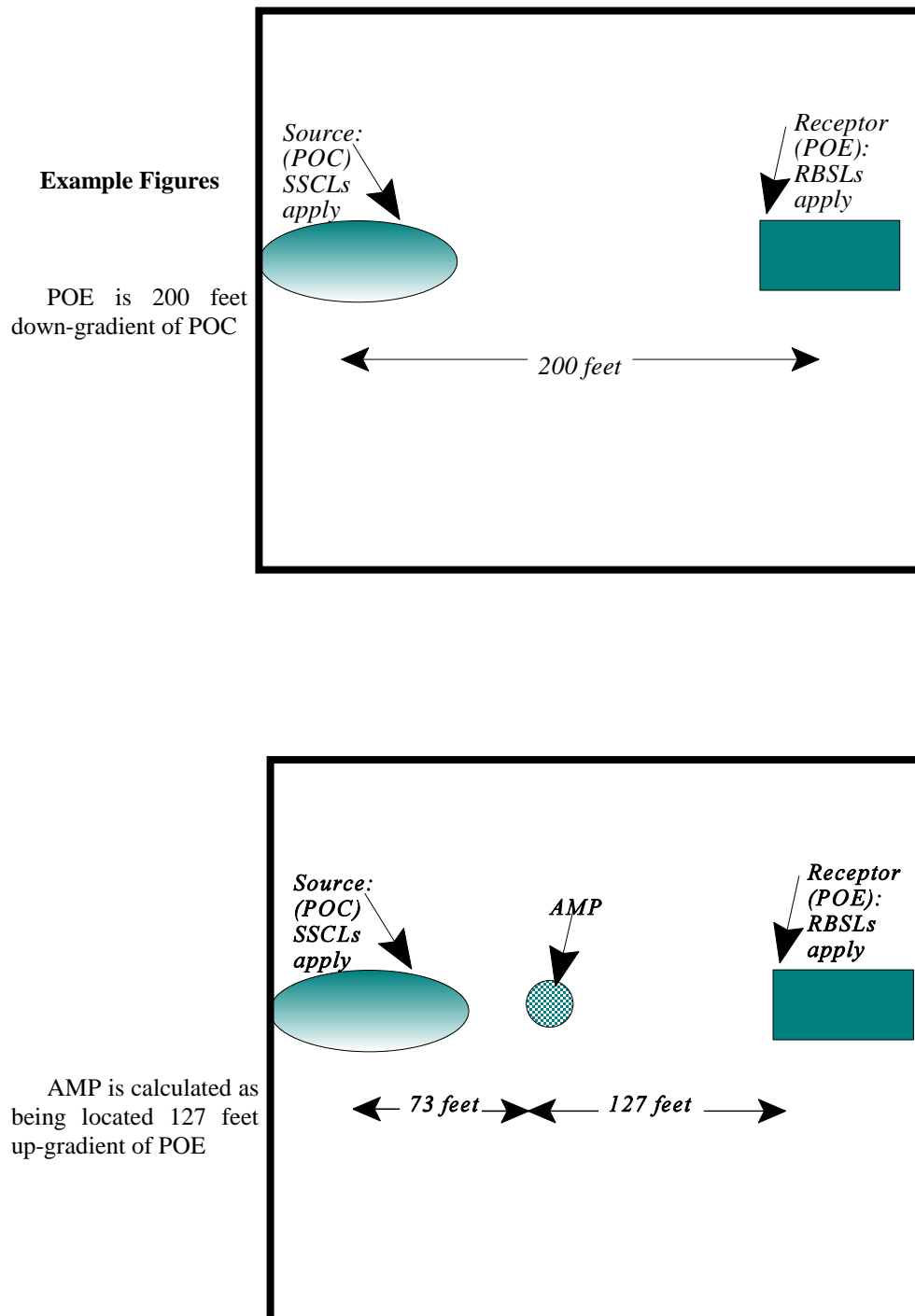
Example Parameter Values

NOTES: * 1 cm³ = 1 mL

Parameter	Parameter Symbol	Example Parameter Value
Hydraulic Conductivity, ft/day	K	5
Hydraulic gradient, ft/ft	i	0.02
Effective porosity (decimal fraction)	θ_{eff}	0.2
Soil bulk density, g/cm ³ *	ρ_s	1.7
Partition coefficient, mL/g	Kd	Calculated from Koc X foc
Benzene adsorption coefficient, mL/g	Koc	50
fraction of organic carbon in saturated zone (decimal fraction)	foc _{sat}	0.001

NOTES: * 1 cm³ = 1 mL

**Figure C-1: Procedures for Locating Alternate Monitoring Points (AMPs) and Calculating Action Levels (ALs),
continued**



TRANSIENT MODELING DATA REQUIREMENTS

- ✓ Attach input, output and other relevant files.
- ✓ Attach applicable graphics for each time step and for each model used.
- ✓ Provide a detailed discussion in Worksheet #1, Section H, of modeling input that is specific to the site, and the model output and results.

Figure C-2: Example of Graphic Modeling Results

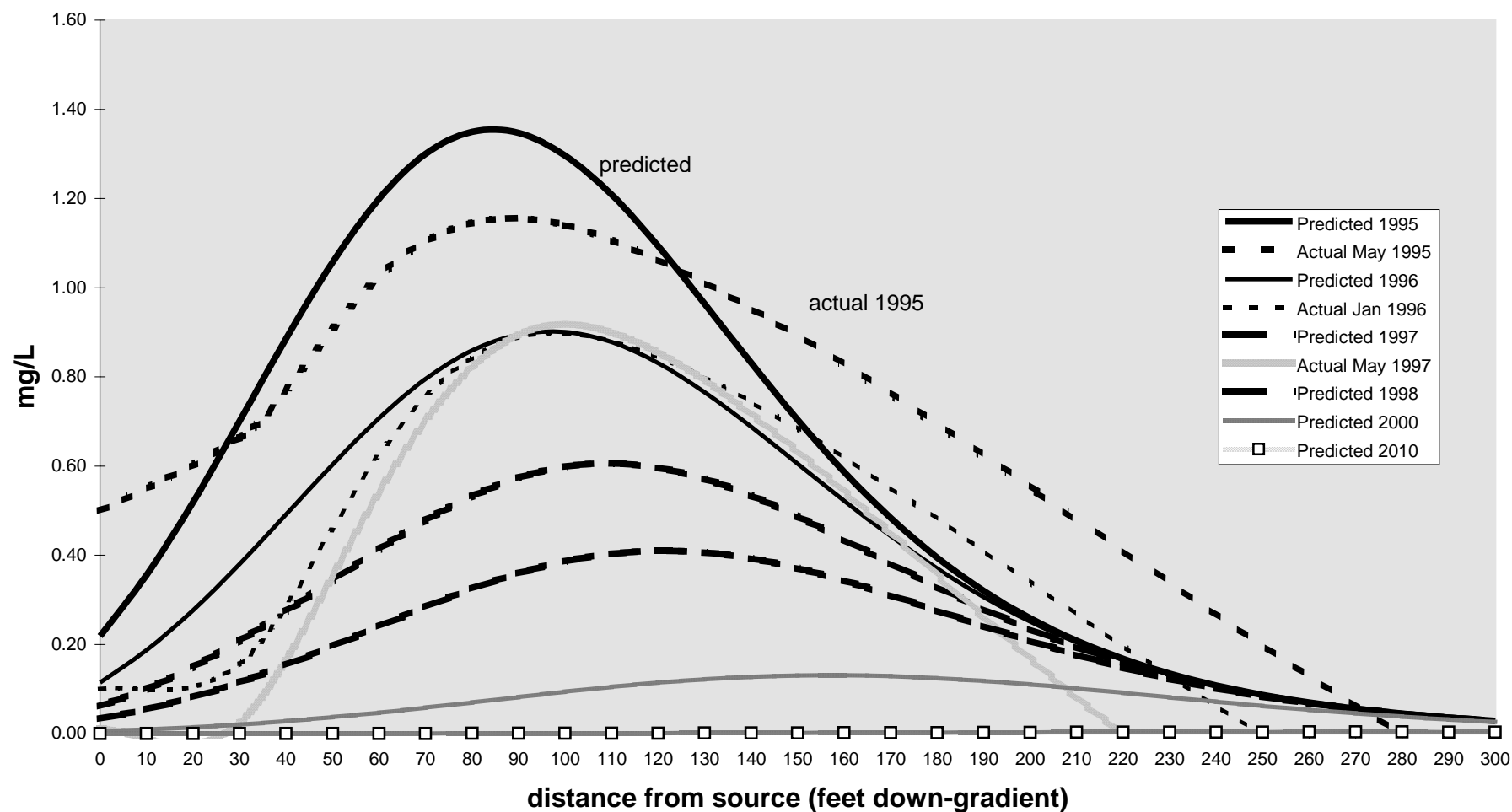


Figure C-3

Example of BIOSCREEN MODELING RESULTS

BIOSCREEN Intrinsic Remediation Decision Support System
About BIOSCREEN Version 1.2

1. HYDROGEOLOGY

Seepage Velocity*	Vs	206.9 (ft/yr)
or		
Hydraulic Conductivity	K	2.0E-02 (cm/sec)
Hydraulic Gradient	i	0.0038 (ft/ft)
Porosity	n	0.38 (-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5 (ft)
Transverse Dispersivity*	alpha y	2.4 (ft)
Vertical Dispersivity*	alpha z	0.0 (ft)
or		
Estimated Plume Length	Lp	1000 (ft)

3. ADSORPTION

Retardation Factor*	R	1.9 (-)
or		
Soil Bulk Density	rho	1.7 (kg/l)
Partition Coefficient	Koc	38 (L/kg)
Fraction Organic Carbon	foc	0.005 (-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1 (per yr)
or		
Solute Half-Life	t-half	1.00 (year)
or Instantaneous Reaction Model		
Delta Oxygen*	DO	2 (mg/L)
Delta Nitrate*	NO3	0 (mg/L)
Observed Ferrous Iron*	Fe2+	0 (mg/L)
Delta Sulfate*	SO4	0 (mg/L)
Observed Methane*	CH4	0 (mg/L)

5. GENERAL

Modeled Area Length*	500 (ft)
Modeled Area Width*	300 (ft)
Simulation Time*	1 (yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 3 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
0	0
15	0.24
20	2.4
15	0.24
0	0

Source Decay (see Help):

SourceHalfLife*	<1 (yr)
Soluble Mass	or
In NAPL, Soil	0.10 (Kg)

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	0	50	100	150	200	250	300	350	400	450	500
Dist. from Source (ft)	0	50	100	150	200	250	300	350	400	450	500

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE **RUN ARRAY**

View Output **View Output**

Data Input Instructions:

1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

figC-3.xls
DERR Run Name

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

Help Recalculate This Sheet

Paste Example Dataset

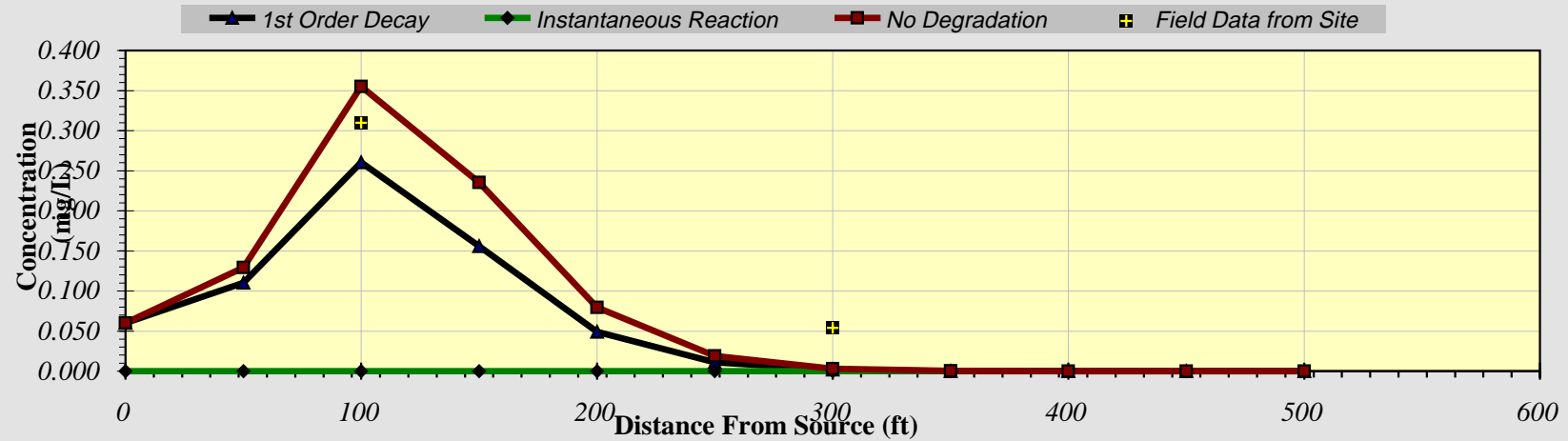
Restore Formulas for Vs, Dispersivities, R, lambda, other

Figure C-3, continued

Example of BIOSCREEN Modeling Results

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft)										
	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.060	0.129	0.355	0.235	0.079	0.019	0.003	0.000	0.000	0.000	0.000
1st Order Decay	0.060	0.110	0.260	0.156	0.049	0.011	0.002	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site			0.310				0.054				



Calculate
Animation

Time:

1 Years

Return to
Input

Recalculate This Sheet

APPENDIX D

Subsurface Investigation Report Guide



State Of Utah
Department of Environmental Quality
Division of Environmental Response and Remediation

Leaking Underground Storage Tank (LUST) Subsurface Investigation Report Guide

A Customer Guide to assist Utah owners and operators of underground storage tanks in their investigation of the extent and degree of petroleum contamination from LUST sites.

October 1999

A petroleum release has been confirmed at your facility, and screening levels have been exceeded. You are therefore required to investigate and remediate the release.

This publication will guide you through the process of preparing the **Subsurface Investigation Report** as required under the state-established compliance schedule(s) for releases of petroleum products from underground storage tank (UST) systems. A subsurface investigation, to define the extent and degree of contamination, is required in order to establish site-specific clean-up levels prior to consideration of closing the release site.

This Subsurface Investigation Report replaces the former versions known as the “Abatement and Initial Site Characterization Report” and the “Subsurface Investigation Report”, formally required under the “Phase I” and “Phase II Reporting and Remediation Schedules”. The “Corrective Action Plan Report” has been replaced by the “Corrective Action Plan Guide.” The former reporting formats should be discontinued immediately.

The former reporting formats have been replaced and they should not be used any more.

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State of Utah
Department of Environmental Quality
Division of Environmental Response and Remediation
Leaking Underground Storage Tank (LUST) Section
168 North 1950 West, First Floor
Salt Lake City, Utah 84116
Telephone: (801) 536-4100
Fax: (801) 359-8853
TDD: (801) 536-4414

Subsurface Investigation and Clean-up Checklist

The following checklist will provide you with a summary of the steps between discovery of a petroleum release, investigation and remediation (clean-up) of your release and final site closure. It is designed to help you understand the steps involved, to graphically track your progress, and show how near to completion of the process you are.

X	Important Steps to Remember
	Report the release within 24 hours of discovery to the Division of Environmental Response and Remediation (DERR). Stop the source of the release and prevent the spread of further contamination.
	If the leak or release occurred from a tank that is covered by the Utah Petroleum Storage Tank Trust Fund (FUND)*, submit an Eligibility Application for reimbursement of investigation and clean-up costs. Refer to the DERR's publication "Petroleum Storage Tank Fund Claims Packet" for complete eligibility and reimbursement information.
	Prepare and submit a "Subsurface Investigation Report" within 90 days of notification from the DERR. Use this guide for preparing the report.**
	If free product is found, prepare a "Free Product Removal Report" and include it with your Subsurface Investigation report. Use this guide for preparing your Free Product Removal Report (page 9).
	Refer to the "Permitting Requirements List" contained in this guide (page 10) for any applicable reporting or permitting requirements by other regulatory agencies for the release at your facility.
	Submit a "Corrective Action Plan", as requested by the DERR, to clean up contamination to established or recommended clean-up levels, or conduct a risk assessment to establish site-specific clean-up levels.
	Once work or clean-up at the site is completed as determined by the DERR, request site closure in the form of a "no further action" letter from the DERR.

Frequently Asked Questions

Why do I have to submit a Subsurface Investigation Report?

There are two reasons why you must submit this report to the Utah Division of Environmental Response and Remediation (DERR). First, you are required by Utah law to report, control, abate and characterize the release by defining the extent and degree of contamination, and conduct remediation (clean-up) if necessary. And second, it will enable the DERR to help guide you through the investigation and clean-up process to make it as timely, site-specific and cost effective as possible. If information regarding your release site indicates relatively high levels of petroleum contamination, further investigation will help determine if there are risks of contaminating drinking water, indoor air, surface water, sensitive wildlife habitats or other sensitive receptors. This report provides information to help determine these potential risks.

The answer to these questions can help get you started.

*Even if the tank is not currently on the Fund, the release may be covered by the Fund if the release occurred while the tank was on the Fund and if the tank was on the Fund within the last six (6) months (or one year in some circumstances). If there is any possibility that the release is covered, the eligibility application should be submitted immediately because the claim will be ineligible if it is not submitted on time. See Utah Code §19-6-524.

**Depending on the results of your subsurface investigation, more work may be needed at the release site. This additional work may consist of conducting groundwater monitoring, abatement or cleanup activities, additional investigations or other related work.

Should I hire a consultant?

Utah law requires that starting on January 1, 1996, contractors or environmental consultants must be certified as a "Certified UST Consultant" to perform work at any UST release site.

You will need to hire the services of a trained and experienced environmental consultant or contractor to assist you with necessary abatement, investigation and clean-up work and associated reports. Environmental professionals with experience in leaking underground storage tank (LUST) site investigations and clean-ups are available to help you with this work in a timely and cost effective manner. It is in your best interest to get several competitive bids before beginning the work. The DERR has a list of contractors and certified consultants available upon request. The State of Utah does not endorse any consultant or company, but maintains this list of contractors who have indicated an ability to perform the required work for your benefit.

Depending on the scope of work to be done at your release site, you may need to use a state-certified environmental consultant.

When do I submit the report?

A Subsurface Investigation Report is due **90** days after receiving this guide from the DERR. Please contact your project manager with any questions regarding your release site or the required report.

How do I file the report?

Submit your Subsurface Investigation Report to your DERR project manager at:

Utah Department of Environmental Quality
Division of Environmental Response and Remediation
Leaking Underground Storage Tank (LUST) Section
168 North 1950 West, First Floor
Salt Lake City, Utah 84116
(801) 536-4100

You can deliver or submit the report in person to this address or you may send it by mail.

What information should the report contain?

The remainder of this guide contains the information necessary for putting together the Subsurface Investigation Report. If you use this guide and include the specific information detailed in it, your report will be complete and will minimize the DERR's review and response time. Also, a complete report will help minimize any additional expense or time on your part for the collection of additional data and information.

COMPONENTS OF THE SUBSURFACE INVESTIGATION REPORT

Create an at-a-glance summary of your report.

Executive Summary

The Executive Summary is a brief summary of this report. It may be as brief as one or two paragraphs and should provide a summary of the information contained in this report and your (or your consultant's) conclusions and recommendations for achieving clean-up and site closure.

A table of contents can work as a checklist assuring the report is complete.

Table of Contents

Your Subsurface Investigation Report's table of contents should contain the following:

1. *Introduction*
2. *Site Description and Maps*
3. *Environmental Sensitivity*
4. *Nature of the Release and Abatement Measures*
5. *Methodology*
6. *Results*
7. *Conclusions and Recommendations*
8. *References and Appendices*
9. *Free Product Removal Report (If applicable)*

1 Introduction

Your introduction should include general information about the site.

The Introduction should include the following information:

- Your facility identification number, release site number and location or address of the release site.
- A brief history of land use at the site including a description of how the release was determined.
- A brief description of the work completed at the site, and a brief summary of the conclusions and recommendations for further work (if any) at the site.

2 Site Description and Maps

A picture is worth a thousand words. Prepare a good site map!

A good site description will help determine potential exposure pathways for petroleum contamination to reach or impact people or the environment. This section should consist of a vicinity and site map providing a complete graphical description of the facility and the land surrounding the facility. Each map should be drawn to scale with proper orientation (showing a North arrow) and should be no larger than 11" x 17". This way the maps can be bound into the report. The maps should provide the following information:

- The facility address or location, with an appropriate scale (e.g., bar scale with 1 inch = 20 feet, etc.) and North arrow.
- Existing and removed UST systems including piping, dispensers and fill ports.
- Underground utilities including: culinary water supply, sewer or septic systems, natural gas lines, storm drains, power and telephone lines.

- Property boundaries, on-site buildings and any adjacent buildings.
- Any excavations showing width, length and depth.
- Any known contaminated areas (square footage or volume if known).
- Location and depths of ALL soil and groundwater samples collected during any phase of the investigation of this release. Include closure sample locations, confirmation sample locations, soil boring locations, groundwater monitoring well location and other relevant information. Be sure to include depth (feet below grade) of sample collection.
- Location of soil stockpiles, aeration piles, etc.
- Land features surrounding the site including; lakes, rivers, streams, irrigation canals, wetlands, slope of local land surface, etc.

Identify all sample locations shown on your site map. Make sure your sample numbers and locations are consistent with the identification labels used on the chain-of-custody forms and the laboratory analytical reports.

If the site map becomes cluttered or confusing due to a large number of sample identification labels, you may wish to use more than one sampling map, or use other techniques to identify the sample locations. You may also include additional site maps showing contaminant iso-concentration contours, geologic cross sections and groundwater elevation contours. You should also present the sampling results in a table format so sample data can be easily referenced to the sample locations marked on the site map.

3 Environmental Sensitivity

This section “Environmental Sensitivity”, describes the environmental features and possible risks to human health or the environment at the release site. These features help to determine risks presented by your release site and its classification status. Site classification is a dynamic process for prioritizing release sites according to the seriousness of the release. The corresponding response action needed is based on the current and potential degree and severity of hazards to human health or the environment. This process is evaluated on a case-by-case basis and ensures that when maximum contaminant limits are exceeded, appropriate response actions are taken to protect human health and the environment. Site classification is based on the most recent data and reflects current site conditions. Since the risks posed by contamination at any given release site are expected to change as more information is learned about a site, a site may be re-classified. Please provide the following information:

- Describe the current land use at, and surrounding the release site. It is considered residential if a residence is located on, or adjacent to your site in any direction.
- Describe the naturally occurring soil type and the depth and location where the samples were obtained. Unified soil classification (USC) is preferred; however, a geologic field description is acceptable (e.g., gravel, sand, silt, clay, etc.), if done by a qualified person.
- Indicate if you encountered groundwater at your site during UST closure, investigation activities, or obtained groundwater information from other sources. If so, indicate the groundwater depth (in feet) below the ground surface at or near your site.
- Groundwater flow direction can be determined if you have at least three (3) groundwater monitoring wells properly installed at your site. You may also be able to determine groundwater flow direction from other wells installed at a nearby LUST release site. Describe which method you used to determine groundwater flow direction.

Environmental Sensitivity affects the clean-up level and subsequent closure of your site. Be as accurate as possible.

Your site classification will help determine if immediate response actions are needed.

Site classification is a dynamic process and can change as more information is obtained.

Identify the product released and describe where the leak occurred.

Have you stopped the release to minimize future problems?

On- or off-site soil treatment such as aeration or land farming needs approval from more than one regulatory agency.

Don't forget to take confirmation samples!

- Indicate the distance and estimated depth (in feet) below grade from the source area of petroleum contamination to the following buried utilities; water line, sanitary sewer, natural gas, storm drain, telephone, electrical, other (specify).
- Indicate the distance (in feet) from the source area of petroleum contamination to property lines and buildings (indicate type of building; residential, commercial, industrial, etc.).
- If available, document the water well survey (e.g., Points of Diversion Information) conducted at the release site.

4 Nature of the Release and Abatement Measures

In this section, you provide details about the release, including age, condition and contents of the UST. You are also required to perform and report abatement measures to stop the source of contamination and to prevent further releases of contamination. Describe the following:

- Age and condition of the UST system, including piping and tanks, corrosion holes, soil staining or odor, sheen on surface of groundwater or surface water.
- Types and amount of product(s) stored in the UST's, and the type and estimated amount of product released into the environment.
- Cause and location of the release such as the tank, dispenser island, piping, overfills and spills, etc.
- The method(s) used for detecting contamination.
- The location of where the contaminated soil or groundwater was either properly disposed of, or is currently being stockpiled or stored.

All stockpiled or aerated soils should be managed in accordance with the DERR'S "Guidelines for Disposition and Treatment of Petroleum-Contaminated Soils". Prior to aeration, approval must be obtained from the local health department, the Utah Division of Air Quality and the DERR. Contact your DERR project manager for assistance with these aeration requirements.

- If contaminated soils are overexcavated, or if groundwater is removed from the release site, confirmation soil or groundwater samples must be taken to confirm that the levels of contamination remaining in-place are at or below established clean-up levels.
- Determine the total volume, contaminant type(s) and concentration(s) of the removed groundwater or soil, and any soil or groundwater contamination remaining in-place.
- Determine the volume, concentration and disposal method or location used for well development or purge water, groundwater, excavation water or other waste water, etc.
- Collect representative environmental samples (soil, groundwater, etc.) to define the nature, extent and degree of the contamination at the site. Information regarding the results of the investigation and plans for future work, if any, should be included in the "Conclusions and Recommendations" section of the report.
- Consult with your DERR project manager or your environmental consultant prior to any confirmation sampling. There may be site-specific requirements necessary for site close-out. See "Sampling Procedures and Requirements" (page 11) for general descriptions of analytical testing requirements for various types of petroleum contamination.

IMPORTANT: *You must IMMEDIATELY begin removal of any free petroleum product in excess of 1/8 inch thick. Refer to the enclosed Free Product Removal Report (page 9) for more information.*

5 Methodology

This section describes the methods and procedures used to conduct the investigation and should include the following:

- Document that all the proper agencies have been contacted and that all necessary permits or approvals have been obtained. Refer to the list of agencies in the "Permitting Requirements List" (page 10) to determine if you need their involvement or approval.
- Describe all methods of investigation used to define the extent and degree of soil and groundwater contamination. This may include on- or off-site soil borings by drilling or direct-push methods, groundwater monitoring wells, soil vapor surveys, overexcavation, test pits, etc.
- Describe each of the following for all groundwater monitoring well installations:
 - Method of drilling or other types of placement of wells (such as digging, backfilling or direct-push techniques).
 - As-built drawings to document well construction.
 - How drill cuttings were disposed.
 - Explain the method used to survey all groundwater wells for elevation and their relative location.
- Include the following information to document soil conditions and sampling procedures:
 - Describe the visual appearance of the soil, including odor, staining, depth to static water level, thickness of capillary fringe and other field observations made during the investigation and soil sampling.
 - Describe native soil type (color, grain size, consistency, hardness, moisture content, etc.) and stratigraphy. This information is collected from soil boring logs, test pits and other methods.
 - Describe your field screening methods, analytical sampling results and other relevant sampling procedures.
- Include the following information to document groundwater conditions and sampling procedures:
 - Describe the visual appearance of the groundwater, odor, sheen or thickness of free product, depth to groundwater (in feet) below grade, general site conditions and other field observations made while measuring static water level (SWL), purging and sampling the wells.
 - Describe method used for purging wells, and how many well casing volumes (total number of gallons) were purged from the well(s).
 - Describe how the SWL measurement was determined.
 - Explain how purge, development or rinsate water generated from wells was disposed.

These descriptions, methods and rationale are generally referred to as your "standard operating procedures" (SOP's). If your SOP's don't substantially change between different sampling events and reports to the DERR, you don't need to describe them again. Simply refer to the previous report.

Do you need to notify any other regulatory agencies? Refer to the Permitting Requirements List to see if you do.

You may need to obtain off-site access agreements to determine the full extent and degree of soil and groundwater contamination.

Describe how the subsurface investigation was conducted.

You may need to conduct quarterly monitoring for a year or so to determine trends in flow direction, contamination levels and depth to groundwater.

Describe the results obtained from your subsurface investigation which should define the extent and degree of soil and groundwater contamination.

Refer to "Sampling Procedures and Requirements" in the Additional Information and Resources section at the end of this guide.

Include your recommendations for clean-up if additional work is needed, or if site closure is warranted with no further action needed at the site.

6 Results

In this section, describe the extent and degree of the contamination from the information you gathered in the field.

- Soil sampling results should include:
 - A description and documentation of the subsurface geology of the site, both soil type and stratigraphy. As part of the documentation, you should include boring logs, excavation or cross-section drawings, test pit information, and any other data you collected.
 - Include any field screening results. Be sure dates, locations, depths and method(s) for soil screening or sampling are clearly identified.
 - A summary of the analytical results developed from laboratory analysis reports should be provided in tabular format. The table should include sample location or other identification number, methods of analyses, depth of sample collection (feet below grade) and results. Copies of the original laboratory analysis reports and chain-of-custody forms must be included in the appendices of the report.
- Groundwater sampling results should include:
 - A groundwater gradient map showing groundwater elevations and flow direction.
 - A summary of the analytical results developed from laboratory analysis reports should be provided in tabular format. The table should include sample location or other identification number, methods of analyses, depth to water (feet below grade) and results. Copies of the original laboratory analysis reports and chain-of-custody forms must be included in the appendices of the report.
 - Dissolved oxygen and any other field parameters (e.g., pH, temperature, redox potential, nitrate, sulfate, etc.) or readings collected in the field, if applicable.
 - Site maps showing current chemical concentration results (e.g., iso-concentration maps) for benzene, naphthalene, etc. Show sampling locations and depths using the same sample ID from the laboratory analytical results table.

7 Conclusions and Recommendations

This section allows you the opportunity to summarize the release site conditions obtained during your investigation, the potential risks they present, and to add your perceptions and recommendations on:

- The extent and degree of the contamination, and the volume and highest contaminant concentrations remaining at the release site.
- Whether or not additional work is necessary, underway or planned in the future in order to achieve clean-up goals.
- Further action required on your part for filing claims against the Petroleum Storage Tank Fund for reimbursement of your investigation and clean-up costs.
- Recommendations for DERR action at your site including extensions of deadlines, assistance with resources such as reimbursement of investigation and clean-up costs from the PST Fund, or site closure with no further action required.

8 References and Appendices

Refer to any outside publications or sources you used for information in preparing this report, or references to documents or reports previously submitted.

Additional documents to be added as appendices, include:

- Soil boring logs and stratigraphic cross sections
- Groundwater monitor well construction logs
- Photographs and other supporting information
- Water well surveys (e.g., Points of Diversion Plots)
- Other agency permits or approval letters if applicable

9 Free Product Removal Report

Free product can be a severe safety hazard as well as a high risk to human health and the environment. If free phase product is observed at any time (e.g., an 1/8" or more of gasoline, diesel or other petroleum products outside the intended storage system), you must immediately begin source removal. Your free product removal procedures should minimize the spread and migration of contamination into uncontaminated areas and must be removed as completely as possible. This Free Product Removal Report section should include:

- Documentation that you notified the Utah Division of Air Quality at (801) 536-4000 for obtaining approvals or permits related to air emissions from your free product recovery system.
- Documentation that you notified the Utah Division of Water Quality at (801) 538-6146 of free product in contact with groundwater or surface water, and that you obtained the necessary permits or approvals for free product disposal or effluent water discharge related to your free product recovery system.
- Site map and tables showing any information pertinent to free product quantity, thickness, type, extent and other relevant details.
- Construction details and other relevant aspects of the free product removal system such as how much was removed, the disposal location or disposal method used and the current site status.
- If water was extracted in conjunction with free product, sample collection may be necessary in order to characterize the effluent (water) quality and dissolved contamination levels. If so, please include all sampling results in the report. Proper procedures, as detailed in the "Sampling Procedures and Requirements" (page 11), should be followed and documented.

Groundwater shall not be disposed of in a manner placing it in direct contact with the environment or which causes contamination to previously uncontaminated areas.

Include any other additional documentation you feel would be helpful in this investigation, clean-up efforts, or to support the conclusions presented.

It may be necessary to file a Free Product Removal Report with your Subsurface Investigation Report.

*Contact other
agencies for
necessary
approvals or
permits.*

ADDITIONAL INFORMATION

Permitting Requirements List

You may need the approval of the following agencies during the course of investigating and remediating petroleum releases. If you have any questions about obtaining approval from other agencies, please contact your DERR project manager at (801) 536-4100.

Utah Division of Air Quality (801) 536-4000

If you anticipate emitting hydrocarbon or petroleum vapors into the atmosphere during any phase of the investigation or clean-up, notify Air Quality so they may determine whether an air discharge permit or approval letter is required. Submit documentation of notification and any permits or approvals to the DERR.

Utah Division of Water Quality (801) 538-6146

If you know that groundwater has been impacted by a free-phase petroleum product, or that surface waters have been contaminated, notify Water Quality. Any required permits or approvals, including groundwater or surface water discharge, pretreatment or injection, must be obtained prior to implementing corrective action or abatement measures. Documentation of the notification and any permits or approvals obtained should be submitted to the DERR.

Utah Division of Solid and Hazardous Waste (801) 538-6170

If you suspect or know the release at your site is a hazardous waste (such as cleaning solvents) or a mixed hazardous/petroleum waste, notify Solid and Hazardous Waste to ensure compliance with permitting, disposal, sampling and other related activities.

Utah Division of Water Rights (801) 538-7240

Contact Water Rights for well installation and abandonment procedures for wells greater than 30 feet below grade, and any other permits required by their Administrative Rules for water well drillers. Submit documentation of the notification and any permits or approvals obtained to the DERR.

Utah Department of Transportation (UDOT) (801) 965-4000

If you need to work in the public right of way for investigation, sampling or any construction activities, call UDOT, city, county or other appropriate agency for the necessary approvals.

Sanitary Sewer District

To discharge petroleum contaminated water or waste water to the local sanitary sewer, check your local listing in the Blue Pages for specific numbers listed under "Public Works" or "Sewer", or call the DERR for more information.

Local Health Department

Contact your local health department or other appropriate agencies (Fire Department, etc.) for any applicable permits, applications or fees they may require for activities related to investigation, construction, corrective action, system operation, disposal or emissions at your release site. These approvals or requirements may vary greatly between different cities or counties.

Blue Stakes (800) 662-4111 or (801) 532-5000

Contact Blue Stakes or other appropriate agency for marking underground public utilities prior to any digging or construction activities.

Sampling Procedures and Requirements

Follow the guidelines and items in this section to ensure that all types of samples collected are of good integrity, are representative of environmental conditions and contaminant levels. Remember that all samples must be collected by an UST Certified Soil and Groundwater Sampler.

- Describe or document any necessary property access and other permitting requirements.
- All soil, groundwater, surface water, or other types of environmental samples must be collected by a Utah certified sampler and analyzed by a Utah certified laboratory. The name and certification number of the sampler and laboratory must be clearly identified.
- Native soil type can be evaluated using Unified Soil Classification methods. Other detailed lithological descriptions may also be necessary.
- Describe subsurface stratigraphy and continuity of strata beneath the site, such as clay, silt or sand lenses, interbedded strata and other features.
- Chain-of-custody protocols and documentation must be maintained and provided for all environmental samples collected.
- All sample identifications, names and numbers should be consistent throughout the chain-of-custody protocol and documentation, laboratory analytical results, site map, data tables and report text.
- Describe sampling methodology, equipment and decontamination procedures.
- Describe the rationale for selecting sample locations and sampled intervals in excavations, test pits, soil/well borings, soil land farms, soil stockpiles or other sample locations. Describe whether the sample location determination was based on field instrument measurements, pre-selected intervals or other rationale.
- Describe and/or illustrate depths at which all soil and/or groundwater samples were collected and show sample locations on a properly scaled and oriented map.
- Identify the sample type(s) collected such as confirmation, grab, composite, headspace, blanks, duplicates, etc., and rationale for their selection.
- Specify the following sampled features and the applicable media sampled, including but not limited to; excavations, test pits, soil borings, soil stockpiles, soil land farms or aeration piles, groundwater monitoring wells, groundwater injection or extraction wells or other types of water wells.
- Provide descriptions of field screening methods and devices used including organic vapor meters or other test methods for detecting the presence of contamination.
- **Sampling procedures must be conducted in a manner which minimizes the loss of volatile organic compounds.** Describe the methods used to minimize the loss of volatiles and maintain sample integrity, such as zero headspace in sample containers and preserving the sample at 4° Celsius.

Following these sampling guidelines will help minimize the need to re-sample. It's important to do it right the first time, so call the DERR with any sampling questions.

Don't forget to take confirmation samples.

Consult this table to determine the right testing methods to use during your investigation and other sampling events. Other fuel types such as kerosene, aviation fuel, etc., may be able to be determined by some of these analytical methods.

- Samples should be immediately delivered to the laboratory. If not, describe the methods used to preserve samples and maintain sample integrity within the applicable holding times.
- Laboratory analytical detection limits must be sufficiently low in order to detect contaminant concentrations at or below their applicable minimum detection levels or state-established clean-up levels.
- Describe the volume removed (gallons), the method used for purging groundwater wells, and the location or method used for the disposal of purge water.
- Groundwater well installation and abandonment must be conducted in accordance with the Utah Division of Water Rights specifications if the wells are deeper than 30 feet below grade.
- If soil borings or wells are emplaced, the following information is required:
 - Type of drilling equipment used, and detailed geologic boring logs with an appropriate vertical scale shown.
 - As-built drawings showing: number of wells and/or borings; total depth of well or boring; well construction materials including casing screen type, length, slot size, filter pack material and particle size;
 - Sample locations for soil or groundwater; and, any organic vapor meter measurements.
 - Type and placement of extraction pumps, if applicable.
 - Identify the depth of groundwater (feet below grade) encountered at the site during sampling or investigations.
 - Describe the volume generated and the procedures used to dispose of drill cuttings, purge water or other waste materials generated during any phase of the work at the release site.
- Confirmation environmental samples (soil, groundwater, etc.) are required any time contamination is treated in-place or removed from the subsurface or release site area.
- Analytical Methods and Contamination Determination: The following table shows the constituents for each product type which must be analyzed using approved analytical methods. Other appropriate analytical methods may be used as approved by the Executive Secretary (UST) for any of the methods outlined below. The analysis of additional constituents may be required as determined by the Executive Secretary (UST).

***Table of Analytical Methods for Sampling
(March 31, 1999)***

Substance or Product Type	Contaminant Compounds to be Analyzed	ANALYTICAL METHODS ¹
		Soil, Groundwater or Surface Water
Gasoline	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, Naphthalene, (BTEXN) and MTBE	EPA 8015B ¹ <u>and</u> EPA 8021B ¹ or 8260B
Diesel	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, and Naphthalene (BTEXN)	EPA 8015B <u>and</u> EPA 8021B or 8260B
Used Oil	Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH); <u>and</u> Benzene, Toluene, Ethylbenzene, Xylenes, Naphthalene (BTEXN) and MTBE; <u>and</u> Halogenated Volatile Organic Compounds (VOC's)	EPA 1664 or 5520 ² <u>and</u> EPA 8021B or 8260B
New Oil	Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH)	EPA 1664 or 5520
Other or Unknown	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, and Naphthalene (BTEXN); <u>and</u> Halogenated Volatile Organic Compounds (VOC's)	EPA 8015B <u>and</u> EPA 8021B or 8260B

¹ The following modifications to these certified methods are considered acceptable by the Executive Secretary (UST):

- Dual column confirmation may not be required for TPH & BTEXN/MTBE analysis.
- A micro-extraction or scale-down technique may be used for aqueous samples.
- Hexane may be used as an extraction solvent.

NOTE: The sample preparation method and any modification(s) to a certified method must be reported by the laboratory on the final analytical report.

² Methods or test procedures allowed for Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH) are 5520(b) or 5520(f) respectively.

Be sure to check with your DERR project manager or your environmental consultant if you have any questions regarding your sampling program or corrective action plan requirements. Some suggestions or ideas to consider when developing your sampling, operation or maintenance plan may include:

- Take both types of samples (e.g., soil and groundwater) if groundwater was encountered during the course of soil sampling.
- Take two or more soil samples in selected locations to better define the vertical extent of contamination. This data will aid in clean-up or closure evaluations.
- Conduct continuous sampling of soil boring(s) or collect multiple samples per location to better define the native soil type, contaminated interval or vertical profile, geological features and related items.
- Upgrade your analytical method(s) to get more complete information during the initial sampling events and minimize re-sampling events.
- Have enough budget set aside to be flexible in the number of actual samples submitted for laboratory analyses, or the number of soil borings or groundwater monitoring wells drilled, etc.
- Check with other regulatory agencies to ensure sampling meets with their requirements for waste disposal or other related items.
- Obtain any necessary off-site access agreements or highway easements for potential work outside your property boundaries in determining the extent and degree of subsurface soil and groundwater contamination.
- For vapor, air, or any other type of environmental sampling, determine the appropriate analytical method and sampling procedures prior to field collection.

Some suggestions to make your sampling more cost effective and to provide more information during the initial sampling event(s).

APPENDIX E-1

Corrective Action Plan Guide



State of Utah
Department of Environmental Quality
Division of Environmental Response and Remediation

Leaking Underground Storage Tank (LUST) Corrective Action Plan Guide

A Customer Guide to assist Utah owners and operators
of underground storage tanks in their clean-up of
petroleum contamination from LUST sites.

October 1999

A petroleum release has been confirmed at your facility, and contamination exceeds clean-up screening levels. You are therefore required to investigate and remediate the release.

This publication will guide you through the process of preparing the **Corrective Action Plan** as required under the state-established compliance schedule(s) for releases of petroleum products from underground storage tank (UST) systems. Clean-up of petroleum contamination is required to meet state-established clean-up levels which are usually based on site-specific conditions in order to properly protect human health and the environment at the release site, and other impacted areas.

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State of Utah
Department of Environmental Quality
Division of Environmental Response and Remediation
Leaking Underground Storage Tank (LUST) Section
168 North 1950 West, First Floor
Salt Lake City, Utah 84116
Telephone: (801) 536-4100
Fax: (801) 536-4242
TDD: (801) 536-4414

Corrective Action Plan (CAP) Checklist

The following checklist will provide you with a summary of the steps between discovery of a petroleum release, investigation, and remediation (clean-up) of your release and final site closure. It is designed to help you understand the steps involved, to graphically track your progress, and show how near to completion of the process you are.

X	Important Steps to Remember
	Report the release within 24 hours of discovery to the Division of Environmental Response and Remediation (DERR). Stop the source of the release and prevent the spread of further contamination.
	If the leak or release occurred from a tank that has a valid certificate of compliance, submit an Eligibility Application for reimbursement of investigation and clean-up costs from the Utah Petroleum Storage Tank (PST) Fund. Refer to the DERR's publication "Petroleum Storage Tank Fund Claims Packet" for complete eligibility and reimbursement information.
	Prepare and submit a "Subsurface Investigation Report" within 90 days of notification from the DERR. See the Subsurface Investigation Report Guide for more details on this scope of work.
	If free product is found, prepare a "Free Product Removal Report" and include it with your Subsurface Investigation Report or your Corrective Action Plan, if needed. Use this guide for preparing your Free Product Removal Report (pg 10).
	Refer to the "Permitting Requirements List" contained in this guide (pg 7) for any applicable reporting or permitting requirements by other regulatory agencies for the release at your facility.
	Submit a "Corrective Action Plan" within 90 days of notification from the DERR, to clean-up contamination to established clean-up levels. Use this guide for preparing the report.
	Once work or clean-up at the site is completed as determined by the DERR, request site closure in the form of a "no further action" letter from the DERR.

Frequently Asked Questions

Why should I submit a Corrective Action Plan?

The answer to these questions can help you get started.

There are two reasons why you must submit this report to the Utah Division of Environmental Response and Remediation (DERR). First, you are required by Utah law to report, control, abate and characterize the release by defining the extent and degree of contamination, and conduct remediation (clean-up) if necessary. And second, it will enable the DERR to help guide you through the investigation and clean-up process to make it as timely, site-specific and cost effective as possible. If information regarding your release site indicates relatively high levels of petroleum contamination, further investigation will help determine if there are risks involved of contaminating drinking water, indoor air, surface water, sensitive wildlife habitats

or to otherwise potentially harm human health or the environment. The Subsurface Investigation Report provides information to help determine these potential risks. This Corrective Action Plan (CAP) guide will help you through the clean-up process and enable you to turn in a more complete corrective action plan for the DERR's review and approval prior to implementation.

Should I hire a consultant?

Utah law requires that after December 31, 1995, contractors or environmental consultants must be certified as a "Certified UST consultant" to perform work at any UST release site.

You will need to hire the services of a trained and experienced environmental consultant or contractor to assist you with necessary abatement, investigation and clean-up work and associated reports. Environmental professionals with experience in leaking underground storage tank (LUST) site investigations and clean-ups are available to help you with this work in a timely and cost effective manner. It is in your best interest to get several competitive bids before beginning the work. The DERR has a list of consultants available upon request. The State of Utah does not endorse any consultant or company, but maintains this list of contractors and consultants who have indicated an ability to perform the required work for your benefit.

You will need to use a state-certified environmental consultant to complete your corrective action plan.

When do I submit the report?

A Corrective Action Plan is due **90** days after receiving this guide from the DERR. Please contact your project manager with any questions regarding your release site, or the required report(s).

How do I file the report?

Submit your Corrective Action Plan to your DERR project manager at:

Utah Department of Environmental Quality
Division of Environmental Response and Remediation
Leaking Underground Storage Tank (LUST) Section
168 North 1950 West, First Floor
Salt Lake City, Utah 84116
(801) 536-4100

You can deliver the report in person to this address, or you may send it by mail.

What information should the report contain?

The remainder of this guide contains the information necessary for putting together the Corrective Action Plan. If you use this guide and include the specific information detailed in it, your report will be complete and will minimize the DERR's review and response time. Also, a complete report will help minimize any additional expense or time on your part for the collection of additional data and information.

COMPONENTS OF THE CORRECTIVE ACTION PLAN

Executive Summary

Create an at-a-glance summary of your report.

The Executive Summary is a brief summary of the report. It can be as brief as one or two paragraphs and should provide a summary of the information contained in this report. Generally, this section should discuss the proposed corrective action and why it was chosen.

Table of Contents

Your Corrective Action Plan's Table of Contents should include the following sections which are described below:

A table of contents can work as a checklist, assuring the report is complete.

1. *Introduction*
2. *Corrective Action Comparison and Selection*
3. *Corrective Action Design and Construction Details*
4. *Permitting Requirements*
5. *Public Notification*
6. *Sampling and Monitoring Plan*
7. *References and Appendices*

1 Introduction

The introduction section should include the following information:

Your introduction should include general information about the site.

- Your facility identification number, release site number and location or address of the release site.
- The purpose and objectives of the corrective action.
- A brief description of the work completed at the site, and an updated site map.

2 Corrective Action Comparison and Selection

This section should list some of the cleanup options with their estimated duration, approximate costs, and relative effectiveness, appropriate for your release site conditions. It should include:

Include a general comparison of alternative clean-up methods that were considered but not chosen, as well as justification for the preferred clean-up option.

- A profile of remedial selections and screening data, including:
 - Cost comparisons, considering both initial capital costs and sampling, operations and maintenance costs.
 - Feasibility of clean-up technologies, based on such factors as soil type, depth to groundwater, extent of contamination, contamination characteristics, hydraulic conductivity, etc.
 - Current land use at the site and anticipated future land use at the site.
 - Availability of land for remedial activity.
- A discussion of the selected corrective action technology and the rationale for its selection.

3 Corrective Action Design and Construction Details

This section should contain site-specific design and construction details of the selected corrective action technology and should include:

- A complete set of appropriately scaled construction drawings showing locations and engineering details.
- Design criteria & supporting calculations for sizing & locating the various clean-up components, including equipment & other technical specifications.
- Operations and maintenance specifications including:
 - A description of the type of operations and maintenance required for the proposed corrective action. Also discuss safety and security measures, and identify who is responsible for providing it.
 - A sampling and monitoring schedule for the corrective action.
 - An emergency response plan.
- Calculated removal rates of contaminants, estimated efficiency of the system, and the expected duration of the cleanup process.
- Document that any necessary approvals or permits were obtained from other regulatory agencies (page 7).

Include specific details of the corrective action scheme that was chosen.

A picture is worth a thousand words. Prepare good maps and drawings.

4 Permitting Requirements

You may need the approval of different regulatory agencies during the course of remediating petroleum releases. Please refer to the enclosed “Permitting Requirements List” (page 7) for more information. If you have any questions about obtaining approval from other agencies, please contact your DERR project manager at (801) 536-4100.

5 Public Notification

Prior to implementing any corrective action, the potentially affected public must be notified of the corrective action. The Executive Secretary (UST) requires public notification by a means designed to reach the segment of the public who may be directly affected by the release or the corrective action process. These methods may include personal contact or notice, notice in newspapers or flyers, or other appropriate methods.

A public notice must contain the following information:

- The name and address of the release site.
- A brief summary of the release and the site conditions.
- The purpose of the corrective action.
- The name and telephone number of your DERR project manager.
- The location, dates and time where the corrective action plan may be viewed by the public.

You must provide verification of this public notification to your DERR project manager. This verification may consist of newspaper tearsheets, certified mail receipts, or a list of the households and businesses which are potentially affected and who have been notified.

Public notification may be required prior to any corrective action plan implementation at your release site.

If significant concerns are raised by impacted individuals and/or businesses, the DERR may require and schedule a public meeting to address these concerns. Public notification must be approved by the Executive Secretary (UST) and posted prior to any implementation of the Corrective Action Plan.

6 Sampling and Monitoring Plan

This section contains your plan for sampling and monitoring during the cleanup process, until verification (confirmation sampling) that the contamination has reached the required clean-up levels. Following the DERR's approval of your sampling and monitoring plan, the associated reports must be submitted according to the approved schedule. The reports should show chronological progress of the CAP and the current status or levels of the contamination. This section and plan should include:

- A sampling protocol for the corrective action plan, as specified in the "Sampling Procedures and Requirements" section (page 8).
- Sampling methodology and analytical methods to be used.
- The location and depth, frequency and rationale for selection of all samples collected.
- The certified sampler and laboratory you plan to use for sample collection and analyses.

You will be required to submit a Post-Remedial Verification Report to the DERR after the corrective action is completed and the site is ready for close-out. This report verifies and documents the effectiveness of the corrective action plan implemented at your release site.

Please see the enclosed "Sampling Procedures and Requirements" (page 8) for additional information.

7 References and Appendices

Refer to any outside publications or sources you used for information in preparing this report, or references to documents or reports previously submitted.

Additional documents may be added as appendices, including:

- Manufacturers technical specifications for remedial equipment.
- Soil boring or groundwater monitor well construction logs.
- Photographs and other supporting information.
- Engineering or technical drawings or schematics.
- Other agency permits or approval letters, if applicable.
- Proof of public notification.
- Laboratory results and Chain of Custody forms.

Make sure your consultant is using a sampling program best suited to your release site conditions.

Additional information and documents related to your clean-up plan can be included as appendix items.

ADDITIONAL INFORMATION

Permitting Requirements List

You may need the approval of the following agencies during the course of investigating and remediating petroleum releases. If you have any questions about obtaining approval from other agencies, please contact your DERR project manager at (801) 536-4100.

Contact other agencies for necessary approvals or permits.

Utah Division of Air Quality (801) 536-4000

If you anticipate emitting hydrocarbon or petroleum vapors into the atmosphere during any phase of the investigation or clean-up, notify Air Quality so they may determine whether an air discharge permit or approval letter is required. Submit documentation of notification and any permits or approvals to the DERR.

Utah Division of Water Quality (801) 538-6146

If you know that groundwater has been impacted by a free-phase petroleum product, or that surface waters have been contaminated, notify Water Quality. Any required permits or approvals, including groundwater or surface water discharge, pretreatment or reinjection, must be obtained prior to implementing corrective action or abatement measures. Documentation of the notification and any permits or approvals obtained should be submitted to the DERR.

Utah Division of Solid and Hazardous Waste (801) 538-6170

If you suspect or know the release at your site is a hazardous waste (such as cleaning solvents) or a mixed hazardous/petroleum waste, notify Solid and Hazardous Waste to ensure compliance with permitting, disposal, sampling and other related activities.

Utah Division of Water Rights (801) 538-7240

Contact Water Rights for well installation and abandonment procedures for wells greater than 30 feet below grade, and any other permits required by their Administrative Rules for water well drillers. Submit documentation of the notification and any permits or approvals obtained to the DERR.

Utah Department of Transportation (UDOT) (801) 965-4000

If you need to work in the public right of way for investigation, sampling or any construction activities, call UDOT, the city, the county or other appropriate agency for the necessary approvals.

Sanitary Sewer District

To discharge petroleum contaminated water or waste water to the local sanitary sewer, check your local listing in the Blue Pages for specific numbers listed under "Public Works" or "Sewer", or call the DERR for more information.

Blue Stakes (800) 662-4111 or (801) 532-5000

Contact Blue Stakes or other appropriate agency for marking underground public utilities prior to any digging or construction activities.

Following these sampling guidelines will help minimize the need to re-sample. It is important to do it right the first time, so call the DERR with any sampling questions.

Local Health Department

Contact your local health department or other appropriate agencies (Fire Department, etc.) for any applicable permits, applications or fees they may require for activities related to investigation, construction, corrective action, system operation, disposal or emissions at your release site. These approvals or requirements may vary greatly between different cities or counties.

Sampling Procedures and Requirements

Follow the guidelines in this section to ensure that all types of samples collected are of good integrity, and are representative of environmental conditions and contaminant levels. Remember that all samples must be collected by an UST Certified Soil and Groundwater Sampler.

- Describe or document any necessary property access and other permitting requirements.
- All soil, groundwater, surface water, or other types of environmental samples must be collected by a Utah certified sampler and analyzed by a Utah certified laboratory. The name and certification number of the sampler and laboratory must be clearly identified.
- Native soil type can be evaluated using Unified Soil Classification methods. Other detailed lithological descriptions may also be necessary.
- Describe subsurface stratigraphy and continuity of strata beneath the site, such as clay, silt or sand lenses, interbedded strata and other features.
- Chain-of-custody protocols and documentation must be maintained and provided for all environmental samples collected.
- All sample identifications, names and numbers should be consistent throughout the chain-of-custody protocol and documentation, laboratory analytical results, site map, data tables and report text.
- Describe sampling methodology, equipment and decontamination procedures.
- Describe the rationale for selecting sample locations and sampled intervals in excavations, test pits, soil/well borings, soil land farms, soil stockpiles or other sample locations. Describe whether the sample location determination was based on field instrument measurements, pre-selected intervals or other rationale.
- Describe and/or illustrate depths at which all soil and/or groundwater samples were collected and show sample locations on a properly scaled and oriented map.
- Identify the sample type(s) collected such as confirmation, grab, composite, headspace, blanks, duplicates, etc., and rationale for their selection.
- Specify the following sampled features and the applicable media sampled, including but not limited to; excavations, test pits, soil borings, soil stockpiles, soil land farms or aeration piles, groundwater monitoring wells, groundwater injection or extraction wells or other types of water wells.
- Provide descriptions of field screening methods and devices used including organic vapor meters or other test methods for detecting the presence of contamination.
- **Sampling procedures must be conducted in a manner which minimizes the loss of volatile organic compounds.** Describe the methods used to minimize the loss of volatiles and maintain sample integrity, such as zero headspace in sample containers and preserving the sample at 4° Celsius.
- Samples should be immediately delivered to the laboratory. If not, describe the methods used to preserve samples and maintain sample integrity within the applicable holding times.
- Laboratory analytical detection limits must be sufficiently low in order to detect contaminant concentrations at or below their applicable minimum detection levels or state-established clean-up levels.
- Describe the volume removed (gallons), the method used for purging groundwater wells, and the location or method used for the disposal of purge water.
- Groundwater well installation and abandonment must be conducted in accordance with the Utah Division of Water Rights specifications if the wells are deeper than 30 feet below grade.

- If soil borings or wells are emplaced, the following information is required:
 - Type of drilling equipment used, and detailed geologic boring logs with an appropriate vertical scale shown.
 - As-built drawings showing: number of wells and/or borings; total depth of well or boring; well construction materials including casing screen type, length, slot size, filter pack material and particle size;
 - Sample locations for soil or groundwater; and, any organic vapor meter measurements.
 - Type and placement of extraction pumps, if applicable.
 - Identify the depth of groundwater (feet below grade) encountered at the site during sampling or investigations.
 - Describe the volume generated and the procedures used to dispose of drill cuttings, purge water or other waste materials generated during any phase of the work at the release site.
- Confirmation environmental samples (soil, groundwater, etc.) are required any time contamination is treated in-place or removed from the subsurface or release site area.
- Analytical Methods and Contamination Determination: The following table shows the constituents for each product type which must be analyzed using approved analytical methods. Other appropriate analytical methods may be used as approved by the Executive Secretary (UST) for any of the methods outlined below. The analysis of additional constituents may be required as determined by the Executive Secretary (UST).

Don't forget to take confirmation samples.

***Table of Analytical Methods for Sampling
(March 31, 1999)***

Substance or Product Type	Contaminant Compounds to be Analyzed	ANALYTICAL METHODS ¹
		Soil, Groundwater or Surface Water
Gasoline	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, Naphthalene, (BTEXN) and MTBE	EPA 8015B ¹ <u>and</u> EPA 8021B ¹ or 8260B
Diesel	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, and Naphthalene (BTEXN)	EPA 8015B <u>and</u> EPA 8021B or 8260B
Used Oil	Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, Naphthalene (BTEXN) and MTBE; <u>and</u> Halogenated Volatile Organic Compounds (VOC's)	EPA 1664 or 5520 ² <u>and</u> EPA 8021B or 8260B
New Oil	Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH)	EPA 1664 or 5520
Other or Unknown	Total Petroleum Hydrocarbons (TPH); <u>and</u> Benzene, Toluene, Ethyl benzene, Xylenes, and Naphthalene (BTEXN); <u>and</u> Halogenated Volatile Organic Compounds (VOC's)	EPA 8015B <u>and</u> EPA 8021B or 8260B

Consult this table to determine the right testing methods to use during your investigation and other sampling events. Other fuel types such as kerosene, aviation fuel, etc., may be able to be determined by some of these analytical methods.

¹ The following modifications to these certified methods are considered acceptable by the Executive Secretary (UST):

- Dual column confirmation may not be required for TPH & BTEXN/MTBE analysis.
- A micro-extraction or scale-down technique may be used for aqueous samples.
- Hexane may be used as an extraction solvent.

NOTE: The sample preparation method and any modification(s) to a certified method must be reported by the laboratory on the final analytical report.

² Methods or test procedures allowed for Oil and Grease (O&G) or Total Recoverable Petroleum Hydrocarbons (TRPH) are 5520(b) or 5520(f) respectively.

Some suggestions to make your sampling more cost effective and to provide more information during the initial sampling event(s).

Be sure to check with your DERR project manager or your environmental consultant if you have any questions regarding your sampling program or corrective action plan requirements. Some suggestions or ideas to consider when developing your sampling, operation or maintenance plan may include:

- Take both types of samples (e.g., soil and groundwater) if groundwater was encountered during the course of soil sampling.
- Take two or more soil samples in selected locations to better define the vertical extent of contamination. This data will aid in clean-up or closure evaluations.
- Conduct continuous sampling of soil boring(s) or collect multiple samples per location to better define the native soil type, contaminated interval or vertical profile, geological features and related items.
- Upgrade your analytical method(s) to get more complete information during the initial sampling events and minimize re-sampling events.
- Have enough budget set aside to be flexible in the number of actual samples submitted for laboratory analyses, or the number of soil borings or groundwater monitoring wells drilled, etc.
- Check with other regulatory agencies to ensure sampling meets with their requirements for waste disposal or other related items.
- Obtain any necessary off-site access agreements or highway easements for potential work outside your property boundaries in determining the extent and degree of subsurface soil and groundwater contamination.
- For vapor, air, or any other type of environmental sampling, determine the appropriate analytical method and sampling procedures prior to field collection.

Free Product Removal Report

It may be necessary to file a Free Product Removal Report with your Corrective Action Plan.

Free product can be a severe safety hazard as well as a high risk to human health and the environment. If free phase product is observed at any time (e.g., an 1/8" or more of gasoline, diesel or other petroleum products outside the intended storage system), you must immediately begin source removal. Your free product removal procedures should minimize the spread and migration of contamination into uncontaminated areas and must be removed as completely as possible. This Free Product Removal Report section should include:

- Documentation that you notified the Utah Division of Air Quality at (801) 536-4000 for obtaining approvals or permits related to air emissions from your free product recovery system.
- Documentation that you notified the Utah Division of Water Quality at (801) 538-6146 of free product in contact with groundwater or surface water, and that you obtained the necessary permits or approvals for free product disposal or effluent water discharge related to your free product recovery system.
- Site map and tables showing any information pertinent to free product quantity, thickness, type, extent and other relevant details.
- Construction details and other relevant aspects of the free product removal system such as how much was removed, the disposal location or disposal method used and the current site status.
- If water was extracted in conjunction with free product, sample collection may be necessary in order to characterize the effluent (water) quality and dissolved contamination levels. If so, please include all sampling results in the report. Proper procedures, as detailed in the "Sampling Procedures and Requirements" (page 8), should be followed and documented.

Groundwater shall not be disposed of in a manner placing it in direct contact with the environment or which causes contamination to previously uncontaminated areas.

APPENDIX E-2

Risk Assessment Proposal Guide



State of Utah
Department of Environmental Quality
Division of Environmental Response and Remediation

Leaking Underground Storage Tank (LUST) Risk Assessment Proposal Guide

A Customer Guide to assist Utah owners and operators of underground storage tanks in their preparation of a risk assessment proposal for petroleum contamination from LUST sites.

July 1999

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Introduction

As an alternative to performing cleanup to established standards, the Owner/Operator may propose to conduct a Tier 2 Risk Assessment to develop site-specific cleanup levels (SSCLs) for affected soil and groundwater by initially submitting this Risk Assessment Proposal (RAP). The RAP is due within **90 days** of receiving the guide. The purpose of the RAP is to ensure that a Tier 2 Risk Assessment appears to be the most feasible and cost-effective approach for Owners/Operators to meet the criteria outlined in Utah's Cleanup Standards Policy ([Utah Admin. Code R311-211](#)). If the RAP is approved, the Owner/Operator may proceed with a Tier 2 Risk Assessment as outlined in "Guidelines for Utah's Corrective Action Process for Leaking Underground Storage Tank Sites" which is available at Alpha Graphics (located at 140 South Main Street, SLC, Utah) at an approximate cost of \$50.00 per manual. Call Alpha Graphics at (801) 364-8451 to ensure sufficient copies are available (copies can be mailed if requested). Upon completion of the Tier 2 Risk Assessment, a Corrective Action Plan (CAP) must be provided for those areas of affected soil and/or groundwater that exceed the SSCLs. If the RAP is not approved, the Owner/Operator is required to submit a CAP to clean up affected areas to the previously state-established cleanup levels.

To complete the RAP, the Owner/Operator must meet the requirements shown in this RAP guide. The results of the RAP will help form the basis for conducting the site-specific Tier 2 Risk Assessment if approved by the Executive Secretary (UST). For this purpose, the Owner/Operator must complete and submit the enclosed Worksheet #1 for all complete exposure pathways at the site.

INSTRUCTIONS FOR COMPLETING THE RISK ASSESSMENT PROPOSAL (RAP)

1. Complete the Site Conceptual Exposure Model (Worksheet #1 of this guide).
2. Prepare a Risk Assessment Proposal using Sections 1 through 6 shown below as a standard report format.
3. Submit the Risk Assessment Proposal to the DERR within **90 days** of receiving the letter requiring a Corrective Action Plan or a Risk Assessment Proposal.

Section 1: Executive Summary

The Executive Summary is a summary of the Risk Assessment Proposal (RAP). The Executive Summary should be brief (one to two pages in length) and should provide a brief summary and description of:

- a. The name of the facility;
- b. The DERR facility identification number;
- c. The location of the site;
- d. The site history;
- e. Cause, location, nature and extent of contamination, and;
- f. Why a RAP was chosen instead of conducting cleanup or implementing corrective action measures to meet state-established cleanup standards.

Section 2: Source Elimination

Briefly describe how the sources of contamination were eliminated by removal or control. Sources may include the UST system, or any soil or groundwater contamination exceeding Utah's Tier 1 criteria or other applicable standards.

Section 3: Data Requirements

Review Worksheet #2 of DERR's "Guidelines for Utah's Corrective Action Process for Leaking Underground Storage Tanks" to aid in identifying the site-specific data required for a Tier 2 Risk Assessment. Site-specific parameter values are required for each of the four options for conducting a Tier 2 Risk Assessment. Identify the following in the RAP:

- a. The extent and degree of contamination, and the affected area and media for which the Tier 2 Risk Assessment is proposed;
- b. Which option in the Tier 2 Risk Assessment will be used (Options 1, 2, 3, and 4 are available);
- c. Data requirements for the applicable option that have **NOT** been met (see data requirements in Worksheet #2), and;
- d. Transient models that will be used for Option 3 and Option 4.

Section 4: Exposure Control

This section must contain the following:

- a. A completed Site Conceptual Exposure Model (SCEM, Worksheet #1 of this guide);

- b. A description of why exposure pathways marked incomplete on the SCEM are considered incomplete;
- c. A discussion of any current or potential exposures to human health and the environment, and;
- d. Identification and explanation of interim abatement measures and response actions that were implemented or are planned.

For exposure pathways that indicate either potential or current exposure, the Owner/Operator may need to implement interim measures to abate or control the exposure to human health and the environment. The Owner/Operator must evaluate the need for interim abatement measures when the contaminants are at levels that may be hazardous to human health and the environment. Abatement measures will be needed to control near-term impacts while the site evaluation effort proceeds. Abatement measures should be practical and reliable control actions which can be promptly implemented by the Owner/Operator. Examples of abatement measures may include placement of interim soil covers, installation of a vapor extraction system to control vapors, or installation of groundwater recovery wells to achieve hydraulic control of off-site plume migration.

The SCEM identifies the source of the release, the impacted media, the transport mechanisms, the exposure pathways and any potential receptors. The SCEM also identifies the combination of factors that could result in complete exposure pathways and potential human and environmental receptors that could result in potential harmful exposure to the contamination at the site. For the purposes of evaluating whether or not an exposure pathway is complete, the SCEM must also consider short-term construction worker exposure and long-term effects of an expanding or migrating contaminant plume. The Owner/Operator must evaluate the SCEM for all combinations of potential exposure pathways and indicate those that are not complete. For incomplete exposure pathways, the Owner/Operator must provide a brief explanation in this section of their rationale for eliminating the pathway.

The Tier 2 Risk Assessment considers several standard exposure pathways for contaminant migration from the source to receptor(s) via air, soil or groundwater transport mechanisms. Exposure pathways are grouped according to the medium in which the receptor contacts the site contaminants. For a given site, the assessment of any of the exposure pathways is a function of the physical site conditions, which include the transport mechanisms and concentration of the constituents of concern, and the presence and proximity of receptors.

For the purpose of the RAP *only*, an exposure pathway is considered complete when a contaminant concentration in the source zone exceeds the applicable Tier 1 criteria (Utah Tier 1 screening levels and distance to receptors), *and if one or both* of the following conditions exist at the site:

- The mechanism for contaminant transport would be active in the absence of any existing or future control measures, **or**;
- Receptors (points of exposure or “POEs”) could be potentially in contact with the affected media. Note: “Potential” means anticipated changes in site conditions or land use within five to ten years. The POE is defined as the point at which an individual or population may come in contact with contamination originating from a LUST site. For the purpose of this document, the Executive Secretary (UST) has determined that POEs shall include: water supply wells; surface water bodies; structures; and, underground utilities. For risk management purposes, the Executive Secretary (UST) has determined that the first down-gradient property line is to be considered a POE.

All exposure pathways meeting these criteria should be evaluated during the Tier 2 Risk Assessment. For the purpose of the Tier 2 Risk Assessment, for an actual risk to human health or the environment to be present, all three of the following components of a complete exposure pathway must be present at a site:

- An affected source medium;
- A mechanism for contaminant transport, *and*;
- A receptor.

For each exposure pathway, the SCEM has three possible outcomes:

- *Incomplete Pathway*: Exposure pathway does not apply under current site conditions.
- *Complete Pathway/Current Exposure*: Exposure pathway may pose an on-going exposure to receptors at a POE. The Owner/Operator must implement interim response measures, as necessary, and either propose a CAP to conduct cleanup or submit a RAP to conduct a Tier 2 Risk Assessment to calculate/derive SSCLs and to assess the need for possible corrective action.
- *Complete Pathway/Potential Exposure*: Exposure pathway could result in exposure to receptors at a POE under a potential exposure scenario. The Owner/Operator must either propose a CAP to conduct cleanup or propose a RAP to conduct a Tier 2 Risk Assessment to calculate/derive SSCLs and to assess the need for possible corrective action.

Section 5: Corrective Action Technology and Cost Evaluation

Evaluate and compare all applicable and appropriate corrective action technologies for the site which include the economic (cost-effectiveness) and technical feasibility of each technology evaluated, and the ability of each technology to protect human health and the environment. At least three or four technologies should be evaluated, if appropriate. The feasibility analyses must be completed, and should be presented in a simple format like the one shown below:

Corrective Action Technology Evaluated (<i>identify technologies below</i>)	Overall Effectiveness of Cleanup Technology (<i>check one below</i>)			Estimated Cost (U.S. dollars, \$) (<i>show estimated cost of each technology below</i>)
	<i>High</i>	<i>Medium</i>	<i>Low</i>	
Technology 1: _____	_____	_____	_____	\$ _____
Technology 2: _____	_____	_____	_____	\$ _____
Technology 3: _____	_____	_____	_____	\$ _____
Technology 4: _____	_____	_____	_____	\$ _____

Section 6: References and Appendices

Refer to any outside publications, sources or information you used for preparing this proposal, or references to documents or reports previously submitted. Additional documents may be added as appendices, including:

- Soil boring and/or groundwater monitor well construction logs;
- Photographs and other supporting information;
- Engineering or technical drawings or schematics, and;
- Laboratory results and tabulated analytical data.

Worksheet #1: Site Conceptual Exposure Model (modified from GSI, 1995)

INSTRUCTIONS	
<input type="checkbox"/>	1. Mark the small boxes if the specified condition is applicable
	2. Fill in the shutoff valves to indicate that exposure pathway is <u>NOT</u> complete. Exposure pathway may <u>not</u> be complete due to source removal, control, and/or treatment
3. For each complete pathway, identify the cleanup options.	

CAUSES of RELEASE	IMPACTED MEDIUM	TRANSPORT MECHANISM	EXPOSURE PATHWAY	POTENTIAL RECEPTORS*	CLEANUP OPTIONS
<div style="border: 1px solid black; padding: 5px;"> <div style="font-size: 0.8em; margin-bottom: 5px;">(check applicable)</div> <div style="margin-bottom: 5px;"><input type="checkbox"/> Product Storage (tanks/UST)</div> <div style="margin-bottom: 5px;"><input type="checkbox"/> Piping</div> <div style="margin-bottom: 5px;"><input type="checkbox"/> Dispenser</div> <div style="margin-bottom: 5px;"><input type="checkbox"/> Other</div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Surface Soil <3 ft deep** </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Volatilization and Dust Transport </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> SOIL Dermal Contact/Ingestion </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="text-align: center; font-size: 0.8em; margin-bottom: 5px;">Exposed Receptors</div> <div style="display: flex; justify-content: space-between;"> <div> On-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> <div style="display: flex; justify-content: space-between;"> <div> Off-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between;"> <div><input type="checkbox"/> Complete</div> <div><input type="checkbox"/> Current Pathway</div> <div><input type="checkbox"/> Potential</div> </div> <div style="font-size: 0.8em;">Action Required? Yes ___ No ___ if YES, list cleanup options below:</div> </div>
	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Subsurface Soil >3 ft deep** </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Volatilization to Outdoor Air </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> AIR Inhalation of Vapors or Particulates </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="text-align: center; font-size: 0.8em; margin-bottom: 5px;">Exposed Persons</div> <div style="display: flex; justify-content: space-between;"> <div> On-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> <div style="display: flex; justify-content: space-between;"> <div> Off-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between;"> <div><input type="checkbox"/> Complete</div> <div><input type="checkbox"/> Current Pathway</div> <div><input type="checkbox"/> Potential</div> </div> <div style="font-size: 0.8em;">Action Required? Yes ___ No ___ if YES, list cleanup options below:</div> </div>
	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Dissolved Groundwater Plume </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Volatilization to Indoor Air </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> GROUNDWATER Potable Water Use or Property Boundary </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="text-align: center; font-size: 0.8em; margin-bottom: 5px;">Groundwater Users</div> <div style="display: flex; justify-content: space-between;"> <div> On-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> <div style="display: flex; justify-content: space-between;"> <div> Off-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between;"> <div><input type="checkbox"/> Complete</div> <div><input type="checkbox"/> Current Pathway</div> <div><input type="checkbox"/> Potential</div> </div> <div style="font-size: 0.8em;">Action Required? Yes ___ No ___ if YES, list cleanup options below:</div> </div>
	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Free Phase Liquid Plume*** </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Mobile Free Phase Migration </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> SURFACE WATER Recreational Use/ Sensitive Habitat </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="text-align: center; font-size: 0.8em; margin-bottom: 5px;">Surface Water Users</div> <div style="display: flex; justify-content: space-between;"> <div> On-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> None <input type="checkbox"/> </div> </div> <div style="display: flex; justify-content: space-between;"> <div> Off-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between;"> <div><input type="checkbox"/> Complete</div> <div><input type="checkbox"/> Current Pathway</div> <div><input type="checkbox"/> Potential</div> </div> <div style="font-size: 0.8em;">Action Required? Yes ___ No ___ if YES, list cleanup options below:</div> </div>
	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Surface soils, Sediments, or Surface Water </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> Storm water/Surface Water Transport </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <input type="checkbox"/> SURFACE WATER Recreational Use/ Sensitive Habitat </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="text-align: center; font-size: 0.8em; margin-bottom: 5px;">Surface Water Users</div> <div style="display: flex; justify-content: space-between;"> <div> On-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> None <input type="checkbox"/> </div> </div> <div style="display: flex; justify-content: space-between;"> <div> Off-site: Residential <input type="checkbox"/> Sensitive Habitat <input type="checkbox"/> </div> <div> nonresidential <input type="checkbox"/> construction worker <input type="checkbox"/> </div> </div> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div style="display: flex; justify-content: space-between;"> <div><input type="checkbox"/> Complete</div> <div><input type="checkbox"/> Current Pathway</div> <div><input type="checkbox"/> Potential</div> </div> <div style="font-size: 0.8em;">Action Required? Yes ___ No ___ if YES, list cleanup options below:</div> </div>

Notes:

- * "Potential" refers to a projection of 5 to 10 years
- ** Evaluate potential for subsurface soil to be excavated and become surface soil
- *** Free Product is a source that must be eliminated or controlled. See Free Product Removal Report in Subsurface Investigation, Appendix D.

APPENDIX F

Utah's Rule R311-211 Corrective Action Cleanup Standards Policy

R311. Environmental Quality, Environmental Response and Remediation.**R311-211. Corrective Action Clean-up Standards Policy - UST and CERCLA Sites.****R311-211-1. Definitions.**

Definitions are found in Section R311-200.

R311-211-2. Source Elimination.

The initial step in all corrective actions implemented at UST and CERCLA sites is to take appropriate action to eliminate the source of contamination either through removal or appropriate source control.

R311-211-3. Clean-up Standards Evaluation Criteria.

Subsequent to source elimination, clean-up standards for remaining contamination which may include numerical, technology-based or risk-based standards or any combination of those standards, shall be determined on a case-by-case basis, taking into consideration the following criteria:

- (a) The impact or potential impact of the contamination on the public health;
- (b) The impact or potential impact of the contamination on the environment;
- (c) Economic considerations and cost effectiveness of clean-up options; and
- (d) The technology available for use in clean-up.

R311-211-4. Prevention of Further Degradation.

In determining background concentrations, clean-up standards, and significance levels, levels of contamination in ground water, surface water, soils or air will not be allowed to degrade beyond the existing contamination levels determined through appropriate monitoring or the use of other data accepted by the Board or the Executive Secretary as representative.

R311-211-5. Clean-up Standards.

- (a) The following shall be the minimum standards to be met for any clean-up of hazardous substances at a UST or CERCLA facility in Utah:
 - (1) for water-related corrective action, the Maximum Contaminant Limits (MCLs) established under the federal Safe Drinking Water Act or other applicable water classifications and standards; and
 - (2) for air-related corrective action, the appropriate air quality standards established under the Federal Clean Air Act.
 - (3) Other standards as determined applicable by the Board may be utilized.
- (b) Clean-up levels below the MCLs or other applicable water or air quality standards may be established by the Board on a case-by-case basis taking into consideration R311-211-3 and R311-211-4.
- (c) In the case of contamination above the MCL or other applicable water or air quality standards, if, after evaluation of all alternatives, it is determined that applicable minimum standards cannot reasonably be achieved, clean-up levels above these minimum standards may be established on a case-by-case basis utilizing R311-211-3 and R311-211-4. In assessing the evaluation criteria, the following factors shall be considered:
 - (1) quantity of materials released;
 - (2) mobility, persistence, and toxicity of materials released;
 - (3) exposure pathways;
 - (4) extent of contamination and its relationship to present and potential surface and ground water locations and uses;
 - (5) type and levels of background contamination; and
 - (6) other relevant standards and factors as determined appropriate by the Board.

R311-211-6. Significance Level.

- (a) Where contamination is identified that is below applicable MCL's, water classification standards, or air quality standards or where applicable standards do not exist for either the parameter in question or the environmental media in which the contamination is found, the clean-up standard shall be established using R311-211-3 and will be set between background and the observed level of contamination. Should it be determined that the observed level of contamination will be allowed to remain, this becomes the significance level.
- (b) At any time, should continued monitoring identify contamination above the significance level, the criteria of R311-211-3 will be reapplied in connection with R311-211-4 to re-evaluate the need for corrective action and determine an appropriate clean-up standard.

R311-211-7. Interim Policy.

This will serve as an interim rule until the Board chooses to modify it or a federal policy, regulation, or statute applicable to corrective action clean-up levels is established. At the time a federal policy is promulgated this rule will be reviewed for consistency with the federal action and will be modified as appropriate and in accordance with applicable state law.

KEY: petroleum, underground storage tanks
1993

19-6-105
19-6-106

APPENDIX G

Establishing Cleanup Levels Using Tier 1 Screening Criteria

Establishing Cleanup Levels Using Tier 1 Screening Criteria

Introduction

The Utah Division of Environmental Response and Remediation (DERR) has developed a process for establishing cleanup levels for soil and groundwater at leaking underground storage tank (LUST) release sites. Tier 1 screening criteria (Utah Department of Environmental Quality, DERR, 1997) are based on the critical distance(s) from the source area to any receptor or point of exposure (POE). This guidance is used by the DERR when evaluating LUST sites for case closure and/or establishing cleanup standards in accordance with Utah Admin. Code R311-211. Figure G-1 shows the Tier 1 Worksheet used in this site-screening evaluation process.

Figure G-2 outlines the process for establishing soil and groundwater cleanup levels. Figure G-3 shows constituent charts that can be used to determine the allowable preliminary concentrations of constituents dissolved in groundwater at the source area relative to the distance from the source area to a POE (see Figure G-2, Step 4). Use of the charts is valid only if the original source of contamination is eliminated by removal or control, the release is abated, and there is no evidence to suggest that contamination increases with distance from the source area. The source area is defined as the location or affected area of soil and groundwater contaminant concentrations of the Constituents of Concern (COCs) which exceed Tier 1 screening levels (SLs). Receptors are defined as persons, ecological organisms and sensitive habitats that are or may be, affected by a petroleum release. POEs are defined as water supply wells, surface water bodies, underground utility lines, structures and property boundaries, that are or may be, affected by a petroleum release.

Source area SLs are concentrations for each chemical constituent that are assumed to be protective of most POEs that are located a distance of 30 feet (500 feet for water supply wells and surface water bodies) from the source of contamination. Transient contaminant fate and transport solute models were used to simulate a continuous (10 year) point source of contamination equal to the Tier 1 SL in groundwater. It was determined that the Tier 1 SLs in groundwater may attenuate to maximum contaminant levels (MCLs) or detection limits at a distance of approximately 30 feet from the source area. The attenuation over these short distances is generally linear and assumes homogeneous subsurface conditions, general fate and transport mechanisms and non-site-specific hydrogeologic conditions.

The charts shown in Figure G-3 illustrate this linear relationship. The chart for benzene, for example, shows that when the dissolved benzene SL at the source area is 300 $\mu\text{g/L}$ or less, it is expected to attenuate to the MCL (5 $\mu\text{g/L}$ for benzene) within 30 feet down-gradient of the source area. At intermediate distances from the source area points, the chart indicates the expected intermediate value at a specific distance. For example (using the same benzene chart in Figure G-3), when a receptor is located 15 feet away from the source area, the chart indicates that dissolved benzene must be 150 $\mu\text{g/L}$ or less at the source area because that value is generally expected to attenuate to the MCL within 15 feet of the source area.

For soils, if the distance between the source area and a POE is less than the applicable critical distances specified in the Tier 1 screening criteria (Utah Department of Environmental Quality, DERR, 1997), the soil cleanup levels are the Recommended Cleanup Levels (RCLs, Utah Department of Health, BERR, 1990). If the distance between the source area and POEs is equal to or greater than the applicable critical distance, the soil cleanup levels are Tier 1 soil SLs.

Examples

The following examples illustrate how the charts can be used:

Example 1: Closure data are submitted for a site. The only POE is a property line which is located 10 feet from the source area. A water sample collected from the tank excavation exhibits a dissolved benzene concentration of 140 $\mu\text{g/L}$. All other constituents concentrations are below laboratory detection limits. No receptors are present within 1000 feet of the source area. This site fails the Tier 1 screening criteria because the POE is located within 30 feet of the source area. According to the chart, 100 $\mu\text{g/L}$ is the allowable dissolved benzene concentration at the source that is expected

to attenuate to 5 ug/L over the 10 foot distance to the property line. The Owner/Operator may clean up dissolved the benzene concentrations to 100 ug/L, or perform a Tier 2 Risk Assessment to ensure that MCLs will be achieved at the property line POE. Each COC in groundwater must be evaluated according to this same linear relationship.

Example 2: A Subsurface Investigation Report submitted for a site indicates that the source area is located within 10 feet of a building, within 15 feet of a buried utility line, and within 20 feet of a property line. This site fails the Tier 1 screening criteria for benzene in groundwater because the POEs are located within 30 feet of the source area. According to the chart for benzene (see Figure G-3), the cleanup level for benzene is 100 ug/L at the source because the distance to the nearest POE is 10 feet (the building). The Owner/Operator may clean-up dissolved benzene concentrations to 100 ug/L, or perform a Tier-2 Risk Assessment to ensure that the receptors will be protected. Each COC in groundwater must also be evaluated according to the applicable linear relationship shown in Figure G-3.

Example 3: Closure data are received for a site. The only receptor is a building which is located 20 feet from the source area. No other receptors are present within 1000 feet of the site. A water sample collected from the tank excavation exhibits a dissolved benzene concentration of 160 ug/L. According to the chart, 200 ug/L is the allowable dissolved benzene concentration at the source that is expected to attenuate to 5 ug/L over the 20-foot distance to the building. The site passes the Tier 1 screening, provided that the other chemical constituents are also present at concentrations that will attenuate to MCLs within 20 feet according to the linear relationship. Each COC in groundwater must also be evaluated according to the applicable linear relationship shown in Figure G-3.

Figure G-1: Utah's RBCA Tier 1 Worksheet

☛ **Owners/Operators complete the unshaded portions.**

☛ **The Screening Levels are applicable only when the requirements for distance to receptors are met.**

FACILITY INFORMATION																																							
<div style="border-bottom: 1px solid black; margin-bottom: 5px;">Facility Name</div> <div style="border-bottom: 1px solid black; margin-bottom: 5px;">Facility Location and Address (no Box Numbers)</div> <div style="border-bottom: 1px solid black; margin-bottom: 5px;">Facility Owner Name and Address (City/State/Zip Code)</div> <div style="display: flex; justify-content: space-between;"> Facility Owner Phone # () Area Code Phone Number </div>					<div style="text-align: center; font-weight: bold; margin-bottom: 10px;">(for DERR use only)</div> <div style="display: flex; justify-content: space-between;"> <div> Facility ID. # _____ Release ID _____ Notification Date _____ Release Reported By _____ </div> <div> DERR Project Manager: _____ Person Completing Worksheet: _____ </div> </div>																																		
SITE ASSESSMENT INFORMATION																																							
<div style="font-weight: bold; margin-bottom: 5px;">(for DERR use only)</div> <div style="font-weight: bold; margin-bottom: 5px;">a. Site Classification</div> <div style="font-size: small; margin-bottom: 5px;">(use Table A.1 for most precise classification)</div> <div style="margin-bottom: 5px;">Classification: _____</div> <div style="margin-bottom: 5px;">Impacts: _____</div> <div style="margin-bottom: 5px;">Required Response Actions: _____</div>		<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <div style="text-align: center; font-weight: bold; margin-bottom: 5px;">Amount</div> <table style="width: 100%; border-collapse: collapse; font-size: small;"> <tr> <th style="text-align: left;">Product Released</th> <th style="text-align: center;">Size (gal)</th> <th style="text-align: center;">Released (gal)</th> <th style="text-align: center;">& # of USTs</th> <th style="text-align: left;">Cause of Release (if known)</th> </tr> <tr> <td>Gasoline</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td>_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____</td> </tr> <tr> <td>Diesel</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td>_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____</td> </tr> <tr> <td>Waste Oil</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td>_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____</td> </tr> <tr> <td>Unknown</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td>_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____</td> </tr> <tr> <td>Other</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> <td>_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____</td> </tr> </table> </div> <div style="width: 50%;"> <div style="font-weight: bold; margin-bottom: 5px;">b. Contaminant Source Information</div> <div style="margin-bottom: 5px;">Sources Removed: _____ tank _____ piping _____ dispenser _____ free product _____ contaminated soil</div> <div style="margin-bottom: 5px;">Other Information: _____</div> </div> </div>								Product Released	Size (gal)	Released (gal)	& # of USTs	Cause of Release (if known)	Gasoline	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____	Diesel	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____	Waste Oil	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____	Unknown	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____	Other	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____
Product Released	Size (gal)	Released (gal)	& # of USTs	Cause of Release (if known)																																			
Gasoline	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____																																			
Diesel	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____																																			
Waste Oil	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____																																			
Unknown	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____																																			
Other	_____	_____	_____	_____ tank _____ piping _____ dispenser _____ overfill/spill _____ Other: _____																																			
<div style="text-align: center; font-weight: bold; margin-bottom: 5px;">c. Land Use Information</div> <div style="display: flex; justify-content: space-between; font-size: small;"> <div>Current Land Use at the Site: _____ residential _____ commercial _____ industrial</div> <div>Surrounding Neighborhood: _____ residential _____ commercial _____ industrial</div> </div> <div style="font-size: x-small;">(Note: Surrounding land use is Residential if one or more residences share a common property line with the Facility)</div>																																							
<div style="text-align: center; font-weight: bold; margin-bottom: 5px;">d. Soil Information</div> <div style="font-size: small;">Depth to Top and Base of Contaminated Soil (feet below land surface): _____ Top _____ Base</div> <div style="font-size: small;">Soil Type(s): _____ Depth (feet below land surface): _____</div> <div style="font-size: small;">Method of Soil Type Identification (check applicable): _____ Unified Soil Classification _____ Geologist's description</div>																																							
<div style="text-align: center; font-weight: bold; margin-bottom: 5px;">e. Groundwater Information</div> <div style="font-size: small;">Was groundwater present in excavations? _____ Yes _____ No Thickness of Free Product: _____</div> <div style="font-size: small;">Depth to groundwater (feet below land surface): _____</div> <div style="font-size: small;">Is groundwater impacted at any concentration: _____ Yes _____ No</div> <div style="font-size: small;">Groundwater flow direction (circle applicable): E, W, N, S, SE, SW, NE, NW _____ Inferred? _____ Measured?</div> <div style="font-size: small;">Slope direction of surface topography (circle applicable): E, W, N, S, SE, SW, NE, NW</div>																																							
<div style="text-align: center; font-weight: bold; margin-bottom: 5px;">f. Distance from Source to Nearest Potential Receptor</div> <div style="text-align: center; font-size: x-small;">(If any receptors are within 30 feet you must go to Tier 2)</div> <div style="font-size: small;">Receptors (enter distance to each in feet)</div> <div style="font-size: small;">Subsurface Utilities: _____ Water line _____ Sewer line _____ Natural Gas _____ Storm Drain _____ Telephone _____ Electrical _____ Other (specify)</div> <div style="font-size: small;">_____ Property Line _____ Buildings (specify type: _____ Residence _____ Commercial _____ other, specify)</div>																																							
<div style="text-align: center; font-weight: bold; margin-bottom: 5px;">Distance to Other Receptors</div> <div style="text-align: center; font-weight: bold; font-size: small;">(for DERR use only)</div> <div style="text-align: center; font-size: x-small;">(If any receptors are within 500 feet you must go to Tier 2)</div> <div style="font-size: small;">Receptors Within 500 feet (enter distance to each in feet and attach water well data sheets and maps; show facility location on each map)</div> <div style="font-size: small;">_____ Municipal Well _____ Domestic Well _____ Irrigation Well</div> <div style="font-size: small;">_____ Surface water (specify type: lake, stream, creek, river, wetland): _____</div>																																							

Figure G-1: Utah's RBCA Tier 1 Worksheet, *continued*

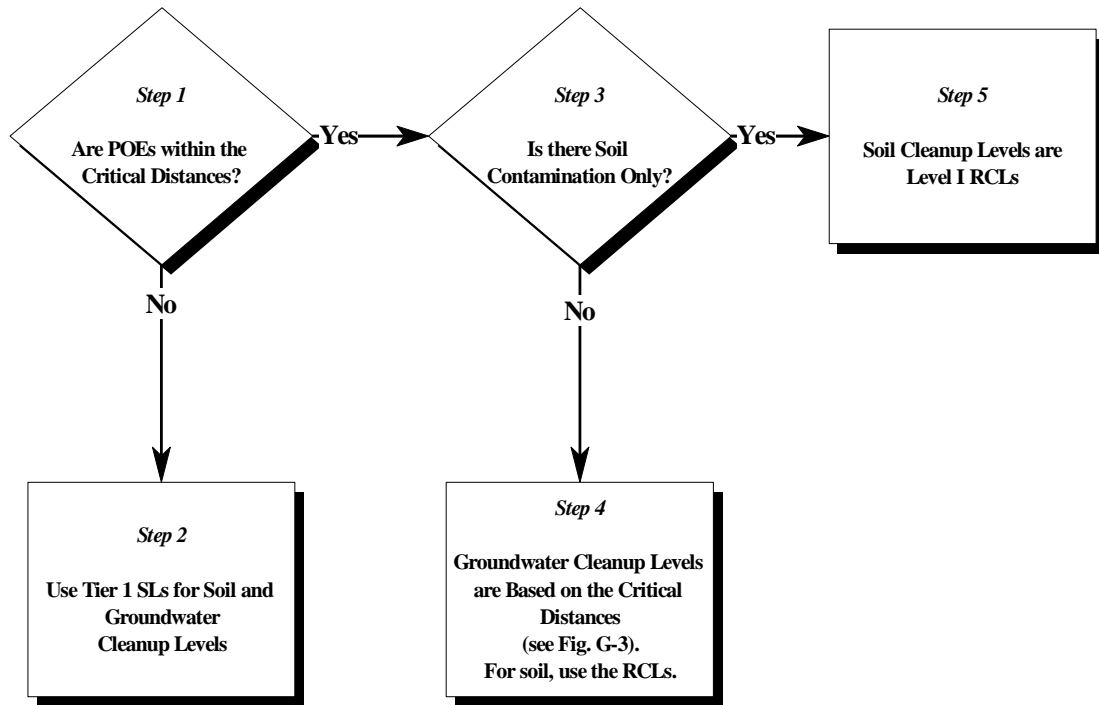
FACILITY SITE MAP	
<p>The owner/operator must submit a facility site map, as close as possible to scale, indicating the north direction, and shows locations of the following properly labeled features:</p> <div style="display: flex; justify-content: space-between;"> <ul style="list-style-type: none"> - Current and/or former UST systems (indicate product type for each) - Utility lines (underground) - Buildings or other structures - Excavations - Soil stockpiles <ul style="list-style-type: none"> - Location of the release and known contamination - Property lines - Monitoring wells - Sample locations </div>	
SUPPLEMENTAL INFORMATION	

Owner/Operator Must Submit Copies of Laboratory Analytical Data for all samples collected

RBCA TIER 1 SCREENING LEVEL EVALUATION (for DERR use only) <i>(The Screening Levels are applicable only when distance-to-receptor criteria are met)</i>				
CONSTITUENTS	Groundwater (mg/L)		Soil (mg/kg)	
	Screening Level	Highest Concentration at Source	Screening Level	Highest Concentration at Source
Benzene	0.3		0.9	
Toluene	7		61	
Ethylbenzene	4		23	
Xylenes	73		235	
Naphthalene	0.1		10	
MTBE	0.2		0.3	
TPH-gasoline	10		1500	
TPH-diesel	10		5000	
Oil and Grease/TRPH	10		10000	

RECOMMENDED TIER 1 ACTIONS (For DERR Use Only)	
	All contaminant concentration levels are below Tier 1 screening levels and no receptors are within the critical distances. <i>Recommendation - No further action.</i>
	All contaminant concentrations are below Tier 1 screening levels but receptors are within the critical distances. <i>Recommendation - Perform a Tier 2 risk assessment or clean up to applicable levels.</i>
	Contaminant concentration(s) exceed Tier 1 screening levels or receptors are within critical distances. <i>Recommendation - Perform a Tier 2 risk assessment or cleanup to applicable levels.</i>
Evaluation completed by: _____ Date _____ <div style="display: flex; justify-content: space-between;"> DERR Project Manager's Signature </div>	
Signature of Person Completing Tier 1 Worksheet if different than DERR Project Manager _____ Date _____	

**Figure G-2: Utah's Process for Establishing
Soil and Groundwater Cleanup Levels
Using Tier 1 Criteria**



NOTES:

POE = Point of Exposure

RCL = Recommended Cleanup Level, BERR, 1990

SL = Screening Level

Figure G-3: Concentrations of Constituents in Groundwater Based on Distance from Source Area to Receptor
All Contaminant Concentrations in $\mu\text{g/L}$

Distance from Source to Receptor (feet)	Benzene*	Toluene*	Ethylbenzene*	Xylenes*	Naphthalene	MTBE	TPH
0	5	1000	700	10000	20	70	500
1	10	1200	810	12000	23	74	817
2	20	1400	920	14200	25	79	1134
3	30	1600	1030	16300	28	83	1451
4	40	1800	1140	18400	31	87	1768
5	50	2000	1250	20500	33	92	2085
6	60	2200	1360	22600	36	96	2402
7	70	2400	1470	24700	38	100	2719
8	80	2600	1580	26800	41	105	3036
9	90	2800	1690	28900	44	109	3353
10	100	3000	1800	31000	46	113	3670
11	110	3200	1910	33100	49	118	3987
12	120	3400	2020	35200	52	122	4304
13	130	3600	2130	37300	55	126	4621
14	140	3800	2240	39400	57	131	4938
15	150	4000	2350	41500	60	135	5255
16	160	4200	2460	43600	63	139	5572
17	170	4400	2570	45700	65	144	5889
18	180	4600	2680	47800	68	148	6206
19	190	4800	2790	49900	71	152	6523
20	200	5000	2900	52000	73	157	6840
21	210	5200	3010	54100	76	161	7157
22	220	5400	3120	56200	79	165	7474
23	230	5600	3230	58300	81	170	7791
24	240	5800	3340	60400	84	174	8108
25	250	6000	3450	62500	87	178	8425
26	260	6200	3560	64600	89	183	8742
27	270	6400	3670	66700	92	187	9059
28	280	6600	3780	68800	95	191	9376
29	290	6800	3890	70900	97	196	9693
30	300	7000	4000	73000	100	200	10000

* Maximum Contaminant Levels for benzene, toluene, ethylbenzene, and xylenes must be met at the receptor (zero feet)

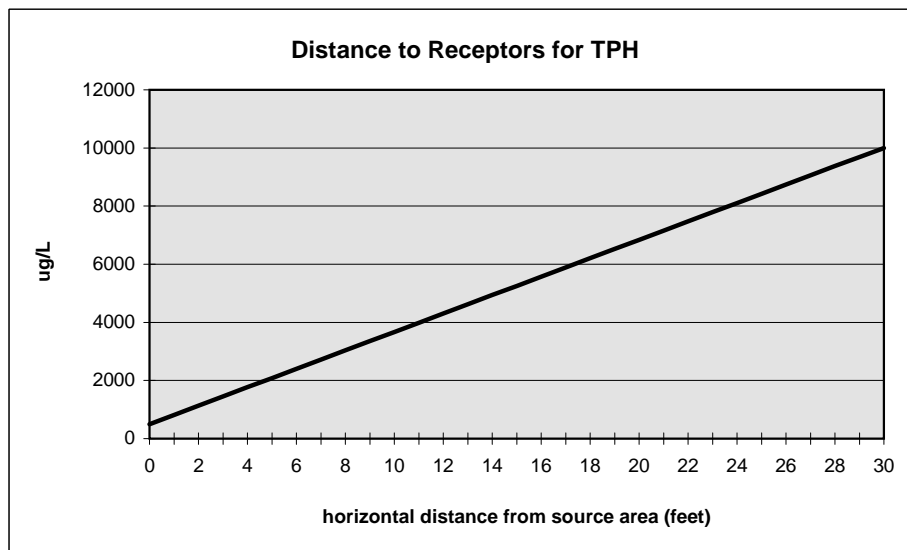
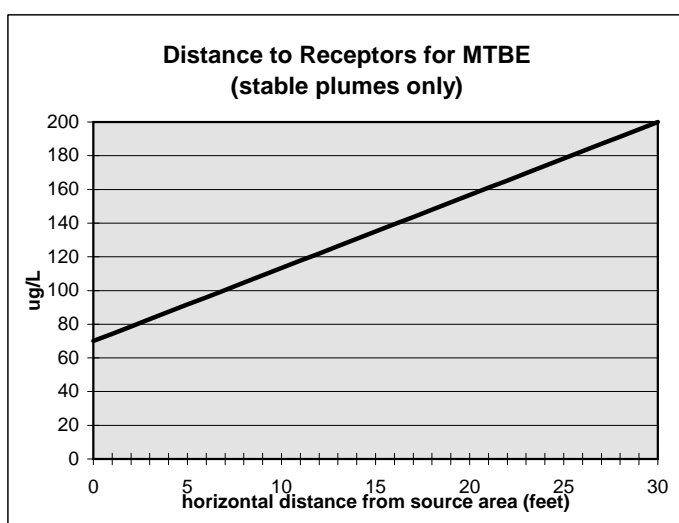
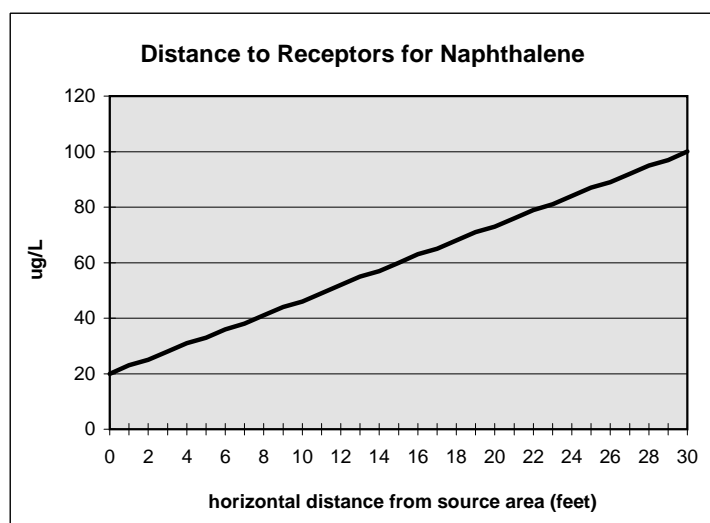
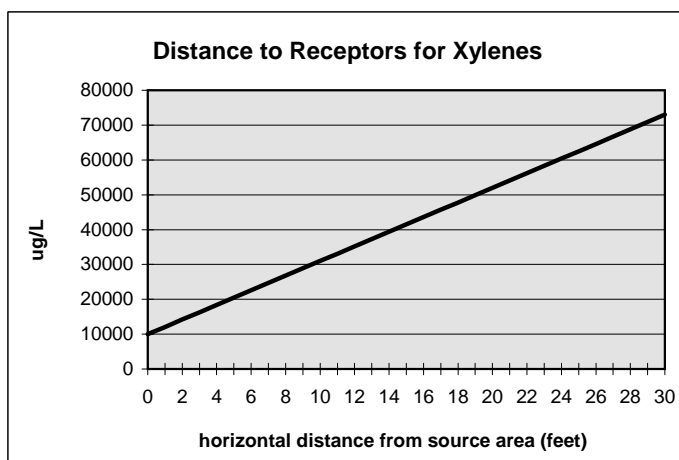
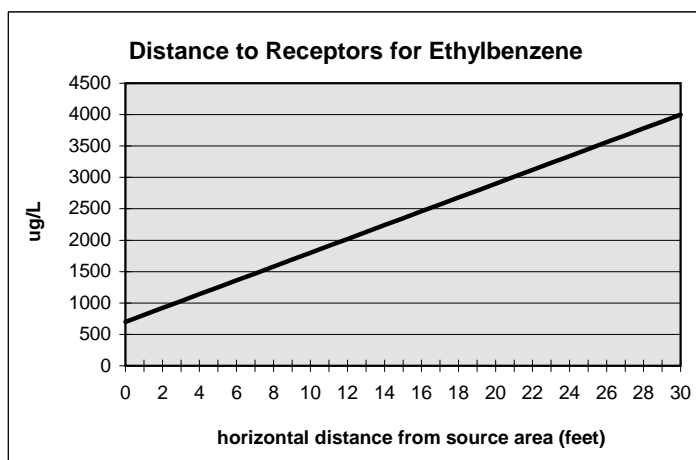
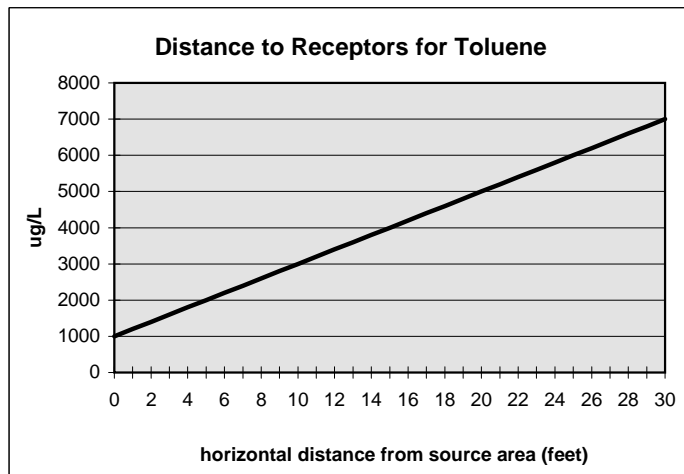
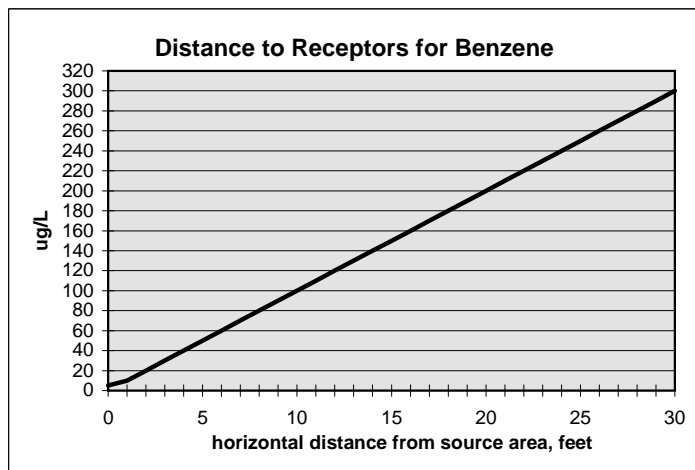


Figure G-3: Concentrations of Constituents in Groundwater Based on Distance from Source Area to Receptor, *continued*



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